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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Flight Motor Set 360L002 (STS-27R) Final Report

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STS-27 POST-TEST NOZZLE PERFORMANCE EVALUATION REPORT

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1.0 INTRODUCTION

A review of the performance and post-flight condition of the STS-27 Redesigned Solid Rocket Motor (RSRM) nozzles is presented in this document. Thermal/Structural instrumentation data is reviewed in Section 4.3 of this report, and applicable Discrepancy Reports (DRs) and Process Departures (PDs) are presented in Section 5.0. The Nozzle Component Program Team (NCPT) performance evaluation and the Redesign Program Review Board (RPRB) assessment is included in Section 6.0.

The STS-27 nozzle assemblies were flown on the RSRM Second Flight (Space Shuttle Atlantis) on 2 December, 1988. The nozzles were a partially submerged convergent/divergent movable design with an aft pivot point flexible bearing. The nozzle assemblies (see Figure 1) incorporated the following features:

a. RSRM forward exit cone with snubber assembly

b. RSRM fixed housing

c. Structural backup Outer Boot Ring (OBR)

d. RSRM cowl ring

e. RSRM nose inlet assembly

f. RSRM throat assembly

g. RSRM aft exit cone assembly with Linear-Shaped Charge (LSC)

h. RTV backfill in Joints 1, 3, and 4

i. Use of EA913 NA adhesive in place of EA913 adhesive

j. Redesigned nozzle plug

k. Carbon Cloth Phenolic (CCP) with 750 ppm sodium content

Figures 2a and 2b show the CCP material usage for the STS-27 forward nozzle and aft exit cone assemblies.

2.0 OBJECTIVES

The RSRM second flight test objectives, as outlined in TWR-18891 (Morton Thiokol, Inc. Requirements Document for RSRM Second Flight), are listed in this section. The test objectives were derived from the CEI Specification CPW1-3600.

AB. Post-flight inspection to verify no gas leaks occurred between the flex bearing internal components (CEI para. 3.2.1.2.3.d).

AF. Demonstration and post-test inspection of exit cone severance (CEI para. 3.2.1.4.5).

AG. Post-flight inspection for flex bearing damage due to water impact (CEI para. 3.2.1.4.7.c).

AH. Demonstrate the performance of the nozzle environmental protection (CEI para. 3.2.1.4.7.c).

AI. Post-flight inspection to verify nozzle liner performance (CEI para. 3.2.1.4.13).

AJ. Demonstrate the exit cone severance ordnance ring (CEI para. 3.2.1.4.12).

AV. Post-flight inspection to verify the nozzle metal parts are reusable (CEI para. 3.2.1.9.b).

AW. Flight demonstration followed by post-flight inspection to verify the flex bearing is reusable (CEI para. 3.2.1.9.c).

BJ. Post-flight inspection to verify remaining nozzle ablative thicknesses (CEI para. 3.3.6.1.2.7).

BK. Post-flight inspection to verify nozzle safety factors (CEI para. 3.3.6.1.2.8).

3.0 CONCLUSIONS AND RECOMMENDATIONS

Compliance to the flight test objectives is discussed below.

AB. Examination of the bearings showed no evidence of flow or erosion between shims. The post-flight flex bearings passed acceptance testing.

AF. Successful severance of both nozzle exit cones was demonstrated.

AG. The flex bearings showed no damage due to water impact and passed post-flight acceptance testing.

AH. The nozzle plugs burst into multiple pieces at motor ignition. No debris or adverse propulsion effects from the nozzle plugs were observed.

AI. The STS-27A and B nozzle liners showed no pocketing or wedgeouts that occurred during motor burn.

AJ. Successful severance of both nozzle exit cones was demonstrated.

AV. There was no STS-27A or B metal housing damage preventing re-use.

AW. The STS-27A and B flex bearings performed nominally during flight and passed post-flight acceptance testing.

BJ. All STS-27A and B nozzle liners showed positive performance margins of safety.

BK. All STS-27A and B nozzle liners showed positive performance margins of safety.

The structural integrity of the nozzle was verified in that the instrumentation data demonstrated positive margins of safety at all locations measured. In general, all strain gage data correlated well with the predicted strain from analysis models as well as data obtained from static test motors. Temperatures tended to be constant throughout the flight and remained in an acceptable range.

4.0 RESULTS/DISCUSSION

4.1 STS-27A (Left-Hand) Nozzle/Flex Bearing Observations

Overall erosion of the STS-27A forward nozzle assembly CCP ablative liner was smooth and uniform. Post-flight subassembly flow surface gaps are shown in Figure 4.1. Eroded chamfer edges were included in the flow surface bond gap measurements. Overall views of the nozzle are shown in Figures 4.2 through 4.6.

4.1.1 STS-27A (LH) Nozzle Components

Test objectives AB, AF, AG, AH, AI, AJ, AV, AW, BJ and BK are satisfied in this section.

STS-27A Aft Exit Cone Assembly

Overall views of the STS-27A aft exit cone fragment are shown in Figures 4.7 through 4.8.

The aft exit cone was severed aft of the compliance ring by the linear-shaped charge. The nozzle severance system performance was nominal. The exit cone cut was clean, with no unusual tearing or breaking.

The remaining aft exit cone fragment showed missing Carbon Cloth Phenolic (CCP) liner 360 degrees circumferentially. Glass Cloth Phenolic (GCP) insulator plies were also torn from the severed end of the exit cone, however no aluminum shell was exposed. These are typical post-flight observations and occur during exit cone severance and at splashdown. The remaining GCP plies showed no signs of heat effect.

The polysulfide groove fill on the forward end of the aft exit cone showed no separations. Post-flight measurements of the polysulfide groove radial width (see Figure 4.9) show that the GCP insulator did not pull away from the aluminum shell during cooldown. The average post-flight radial width of the groove was 0.18 inch. The polysulfide appeared to shrink axially aft a maximum of 0.11 inch (see Figure 4.10).

The forward end of the aft exit cone showed a separation located within the GCP primary O-ring groove extending from 334 to 0 to 108 degrees (see Figure 4.11). The maximum radial dimension of the separation was 0.05 inch. The separation resulted from post-burn heat soak and liner shrinkage, or from splashdown loads.

Performance margins of safety could not be verified on the aft exit cone, as a result of the loss of the CCP liner at LSC ignition and splashdown.

The 45- and 135-degree actuator brackets showed only minor paint chipping and scratching, due to disassembly operations. The compliance ring showed no damage. Minor metal scratches were observed on the aft exit cone shell Outside Diameter (OD) surface at 90, 105 and 109 degrees as a result of cork removal. The worst-case scratch was 0.020 inch deep radially.

STS-27A Forward Exit Cone Assembly

Overall views of the STS-27A forward exit cone are shown in Figure 4.12.

The forward exit cone showed missing CCP liner over the center 10 inches of the cone 360 degrees circumferentially. This is a typical post-flight observation and occurs at splashdown and during Diver Operated Plug (DOP) insertion. The GCP insulator exposed by the missing liner showed no signs of heat effect. The CCP liner remained bonded on the forward 8 to 12 inches and on the aft 12 inches of the cone. The flow surface of the remaining liner showed the typical dimpled erosion pattern that has occurred on all flight and static test forward exit cones (see Figure 4.13). The maximum radial depth of the dimpled erosion was 0.15 inch.

The aft end of the forward exit cone showed no bondline separations between the EA946 adhesive and the steel housing. There were no separations within the GCP insulator or at the GCP/CCP interface. Two small cohesive

separations in virgin CCP occurred at 45 and 120 degrees, and measured 0.008 and 0.005 inch wide radially, respectively (see Figure 4.14). There were no signs of heat effect in, or adjacent to, the separations. This is a typical observation and results from post-burn heat soak and cooldown liner shrinkage, and/or splashdown loads.

The forward end of the forward exit cone also showed no bondline separations. Separations were observed on the forward end of the forward exit cone between the GCP and CCP around most of the circumference. The largest measured 0.060 in. wide radially from 0 to 30 degrees and extended 12 inches axially along the remaining CCP liner (see Figure 4.14). These separations resulted from post-burn heat soak and cooldown liner shrinkage, and/or loads induced by splashdown and DOP insertion.

Sectioning of the FEC liner revealed CCP-to-GCP separations occurring intermittently along the exit cone length and around the circumference. Separations were also observed within the GCP insulator. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.1 presents the STS-27A forward exit cone char and erosion data and performance margins of safety. The margins of safety in this table were

based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.15 shows the locations of the measurement stations on the forward exit cone. All margins of safety were positive with a worst case of 0.07 at Station 1 (90 and 135 degrees).

The forward exit cone housing aft flange 91.8-degree locator pin hole was slightly deformed by the alignment pin during aft exit cone demate. The aft corner of the hole was dented approximately 0.025 inch circumferentially by 0.01 inch axially.

STS-27A Throat Assembly

Overall views of the STS-27A throat assembly are shown in Figures 4.5 and 4.6.

Erosion of the throat and throat inlet rings was smooth and uniform, with no wedgeouts or popped-up charred CCP material observed. The throat post-flight mean diameter was 55.870 inches (erosion rate of 8.24 mils/second based on an action time of 121.9 seconds). Nozzle post-burn throat diameters have ranged from 55.787 to 56.38 inches. The flow surface bondline gap between the throat ring and throat inlet ring was 0.10 inch and is typical of past static test and flight nozzles.

The aft end of the throat assembly showed a bondline separation between the EA913 NA adhesive and throat support housing (see Figure 4.16). The separation measured 0.01 inch wide radially and extended 360 degrees circumferentially. This bondline separation is a typical observation and results from post-burn heat soak and cooldown liner shrinkage. The throat assembly forward end showed no bondline separations.

Sectioned views of the throat and throat inlet ring liner and insulator are shown in Figures 4.17 and 4.18. Sectioning of the liner revealed CCP-to-GCP separations occurring intermittently along the throat inlet ring length and around the circumference. Separations were also observed within the GCP insulator of the throat inlet ring. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.2 presents the STS-27A throat and throat inlet ring char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.19 shows the locations of the measurement stations on the throat assembly. All margins of safety were positive with a worst case of 0.04 at Station 8 (0 degrees).

STS-27A Nose Inlet Assembly

Overall views of the STS-27A nose inlet assembly are shown in Figures 4.5 and 4.6.

The ply angle of the forward nose ring was checked and found to be of the RSRM design. The flow surface bondline gap between the forward nose (-503) ring and aft inlet (-504) ring was 0.15 inch. The flow surface bondline gap between the -503 ring and the nose cap was 0.04 inch. These post-fired measurements are typical of past static test and flight nozzles.

The -503 and -504 rings showed smooth erosion with no pockets or wash areas observed. Wedged out and popped-up charred CCP material was observed on the forward 1.5 to 1.7 inches of the -504 ring intermittently around the circumference (see Figures 4.20 and 4.21). Sharp edges indicate a post-motor burn occurrence time. Impact marks occurring after motor operation appeared on both rings intermittently around the circumference. The largest was on the -504 ring and measured 0.5 inch in diameter by 0.1 inch deep. These marks most likely resulted from the loose aft and forward exit cone CCP material at splashdown.

The nose cap showed smooth erosion with no pockets or major washes observed. The aft 2 inches showed wedged out and popped-up charred CCP material intermittently around the circumference (see Figure 4.22). Sharp

edges indicate a post-motor burn occurrence time. No wedgeouts were observed on the forward end of the nose cap. The forward 1.5 feet of the nose cap flow surface showed typical minor washing (0.10 inch maximum radial depth). Intermittent impact marks occurring after motor operation were observed on the forward tip of the nose cap. The largest measured 0.7 inch in diameter by 0.2 inch deep.

Bondline separations (see Figure 4.23) were observed on the aft end of the nose cap between the metal and EA946 adhesive at 30 degrees (0.002 inch wide radially), and between the adhesive and GCP at 90 to 105, 195, and 315 to 345 degrees (maximum 0.005 inch wide radially). There were no cohesive separations or separations between the GCP and CCP on the nose cap aft end. There were also no separations observed on the -504 aft inlet ring aft end.

Sectioned views of the nose cap, -503 and -504 rings liner and insulator are shown in Figures 4.24 through 4.26. Sectioning revealed CCP-to-GCP separations in the nose cap and -504 ring occurring intermittently along the lengths and around the circumferences of the parts. Separations were also observed within the -503 and -504 rings GCP insulators. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material on all three rings. There was no evidence of heat effect within the virgin material.

Table 4.3 presents the STS-27A -503 and -504 rings char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.27 shows the locations of the measurement stations on the nose inlet assembly. All margins of safety were positive with a worst case of 0.14 at Station 28 (0 and 15 degrees).

Table 4.4 presents the STS-27A nose cap char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.27 shows the locations of the measurement stations on the nose inlet assembly. All margins of safety were 0.00 or greater with a worst case of 0.00 at Station 24 (0 degrees).

During nozzle Joint No. 3 disassembly inspections, a Helicoil in the nose inlet housing 90-degree threaded hole was found to be damaged. Another Helicoil at 100 degrees had approximately 1.5 coils raised above the face of the nose inlet housing. This damage occurred during joint disassembly operations (see Figure 4.28). Refurbishment showed that the 90- and 100-degree aluminum threads of the nose inlet housing were damaged. Twinserts will be fitted in these two threaded holes.

STS-27A Cowl/Outer Boot Ring/Flex Boot

Overall views of the STS-27B cowl and OBR are shown in Figures 4.29 through 4.31. The flow surface bondline gap between the cowl and nose cap was 0.10 inch. The flow surface bondline gap between the cowl and OBR was 0.18 inch. These post-burn gaps are typical of past static test and flight nozzles. All cowl vent holes appeared plugged with slag on the OD of the ring.

Typical erratic erosion was observed intermittently around the cowl circumference. The forward portion of the ring eroded a maximum of 0.15 inch greater than on the aft portion of the ring (see Figures 4.30 and 4.31). This erratic erosion is a result of the low ply angle of the cowl ring and has been observed on the majority of flight and static test nozzles. Cross-ply cracking isolated in charred CCP material extended axially through the vent and shear pin holes. Post-burn wedgeouts and popped-up charred CCP material were observed on the aft 2.5 to 3.0 inches, intermittently around the circumference (see Figure 4.32).

Sectioned views of the cowl ring are shown in Figures 4.33 and 4.34. Ply-lift regions were observed within charred material on the forward half of the ring. Ply lifting has been observed on the majority of sectioned cowl rings and is believed to be a result of the low ply angle.

The cowl forward end showed no bondline separations between the cowl housing and insulator.

The structural backup outer boot ring was intact (see Figures 4.29 through 4.31). The flow surfaces showed smooth erosion with no pockets or major washes. Post-burn wedgeouts and popped-up charred CCP material were observed on the forward 1.5 inches of the OBR intermittently around the circumference (see Figure 4.35). Delaminations in the charred CCP on the aft tip were observed 360 degrees circumferentially. Charred CCP material on the aft tip adjacent to the flex boot fractured and popped up over a majority of the circumference. These are typical observations that have occurred on the majority of static test and flight nozzles.

Sectioned views of the OBR and flex boot are shown in Figures 4.36 through 4.39. Delaminations located in virgin material were observed at the OBR structural back-up/overwrap interface. The delaminations extended the entire axial length of the OBR at 0 and 135 degrees. There were no signs of heat effect within the delaminations.

The vulcanized axial bondline between the flex boot and the OBR showed separations intermittently around the circumference and along the axial length (see Figures 4.36 through 4.39). There were no separations observed which extended the entire axial length of the bondline.

The cowl aft tip remained bonded to the flex boot around the entire circumference (see Figures 4.36 through 4.39). Small voids and cracks were observed within the EA913 NA adhesive. There were no signs of flow between the cowl and flex boot.

The axial bondline between the cowl and OBR showed cohesive and adhesive separations around the circumference, but showed no signs of flow. It is believed that the separations in the axial bondline resulted from post-burn heat soak and cooldown liner shrinkage.

Table 4.5 presents the STS-27A cowl/outer boot ring char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.40 shows the locations of the measurement stations on the cowl and outer boot ring. All margins of safety were positive with a worst case of 0.20 at Station 1 (0 degrees).

The cavity side of the flex boot showed no evidence of flow or erosion. It was uniformly sooted and charred, and appeared typical of previous flight and static test nozzles. A minimum of 3.8 NBR plies remained around the flex boot circumference following the flight. Figure 4.41 presents the flex boot material affected depth per circumferential location, along with the performance margins of safety. The worst-case performance margin of safety was 0.46 and occurred at 300 degrees.

STS-27A Fixed Housing

Overall views of the STS-27A fixed housing assembly are shown in Figures 4.2 through 4.4.

The fixed housing insulation erosion was smooth and uniform. Post-burn wedgeouts of charred CCP material were observed on the forward 2 inches intermittently around the circumference (see Figure 4.42). The maximum radial depth was 0.35 inch. There were no bondline separations observed on the aft or forward end, and the GCP was not heat effected.

Sectioned views of the fixed housing liner and insulator are shown in Figures 4.43 and 4.44. Sectioning of the liner revealed CCP-to-GCP separations occurring intermittently along the length and around the circumference. Separations within the GCP insulator were also observed. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.6 presents the STS-27A fixed housing insulation char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted

to the end of action time, and RSRM minimum liner thicknesses. Figure 4.45 shows the locations of the measurement stations on the fixed housing insulation. All margins of safety were positive with a worst case of 0.66 at Station 3 (180 degrees) and at Station 11 (90 degrees).

STS-27A Bearing Protector

The bearing protector was sooted along the entire length and circumference (see Figures 4.46 and 4.47). Heavier soot and erosion were observed in line with the cowl ring vent holes at the thickened portion. Erosion depths at these locations are presented in Figure 4.48. There was no evidence of heat effect on the inside diameter (ID) surface of the bearing protector.

STS-27A Flex Bearing

Overall flex bearing performance during the flight was acceptable. The bearing showed no damage and no indications of exposure to heating. Pad unbond inspections showed an increase of Pad #1 unbond area from 33.7 in^2 to 74.9 in^2. The total flex bearing pad unbond area (142 in^2) also exceeded specification limits (70 in2). These results were written up on DR 169337. The post-flight bearing passed acceptance testing and was found acceptable for reuse.

4.1.2 STS-27A Nozzle Joints

Descriptions of the five STS-27A nozzle joints follows. The joint flow surface gap openings between each nozzle subassembly are summarized in Figure 4.1. All gaps were typical of previous static test and flight nozzles.

STS-27A Aft Exit Cone-to-Forward Exit Cone (Joint No. 1)

A cross-sectioned view of the STS-27A aft exit cone/forward exit cone field joint is presented in Figure 4.49.

The backfilled RTV extended below the joint char line 360 degrees circumferentially. RTV reached the high pressure side of the primary O-ring groove from 56.25 to 120, 123 to 131.75, 153.75 to 309.5 and 330 to 348 degrees. The primary O-ring did not see pressure.

Examination of the joint showed black and white corrosion appearing between the primary and secondary O-rings, and outboard of the secondary O-ring intermittently around the circumference (see Figures 4.50 and 4.51). The black corrosion is the beginning stage of the aluminum oxide. The corrosion was less than that observed on the STS-26 (LH) and (RH) joints, but more than what was observed on the STS-27 (RH) joint. There was no pitting observed.

A white rubbery substance was observed on the aft end of the forward exit cone on the EA946 adhesive bondline, intermittently around the circumference. The substance was flexible when stretched and adhered to the aft surface. This substance has not previously been observed. Lab analysis showed the substance to be tape adhesive. This observation is discussed further in Section 6.1 of this report.

The forward exit cone housing aft flange 91.8-degree locator pin hole was slightly deformed by the alignment pin during aft exit cone demate. The aft corner of the hole was dented approximately 0.025 inch circumferentially by 0.01 inch axially.

The STS-27(LH) aft exit cone field joint bolts showed no damage.

STS-27A Nose Inlet-to-Bearing Forward End Ring-to-Cowl (Joint No. 2)

A cross-sectioned view of the STS-27A nose inlet/forward end ring/cowl joint is presented in Figure 4.52. Photographs of the post-flight joint are shown in Figures 4.53 through 4.56.

The RTV extended below the joint char line and filled the radial portions of the joint 360 degrees circumferentially. RTV extended to the nose inlet housing from 0 to 4, 96, 180 to 188, and 265 to 274 degrees. There was no

RTV extending to the primary O-ring. EA913 NA adhesive also extended to the nose inlet housing from 89 to 92, 112 to 117, 130 to 142, 180 to 198, 210 to 230, 258, and 325 degrees. EA913 NA adhesive mixed with the RTV 360-deg circumferentially. The adhesive was typically sandwiched between two layers of RTV. Soot was observed on the surface of the RTV, but there was no erosion or heat effect. Distinct blowpaths through the RTV were evident on the radial ID phenolic portion of the joint at 29, 289, 296, and 348 degrees. A possible blowpath was located at 12 degrees on the radial ID phenolic surface. The blowpaths at 29, 289, and 348 degrees eroded through the RTV, but there was no erosion or heat effect to the GCP or SCP. At the 296-degree location, the GCP was charred approximately 0.002 inch deep axially on the nose cap aft end. Soot was observed up to the primary O-ring on the nose inlet housing intermittently around the circumference. The primary O-ring saw pressure, but there was no blowby, erosion or heat effect. Soot also extended to the bolt holes on the forward end of the cowl housing intermittently around the circumference.

The metal housings showed no heat effect. Minor surface scratches were found on the aft end of the nose inlet housing due to the use of jacking screws during joint disassembly.

STS-27A Nose Inlet-to-Throat (Joint No. 3)

A cross-sectioned view of the STS-27A nose inlet/throat joint is presented

in Figure 4.57. Photographs of the post-flight joint are shown in Figures 4.58 and 4.59.

The RTV backfill extended below the joint char line 360 degrees circumferentially. RTV completely filled the radial ID portion of the joint 360 degrees circumferentially, and extended along the axial portion from 0 to 10, 95 to 210, 240 to 270, and 280 to 330 degrees. RTV did not extend onto the radial OD or reach the primary O-ring anywhere around the circumference. There were no RTV voids or blow paths observed in the joint. The primary O-ring did not see pressure.

Corrosion was observed on both sides of the joint inboard of the primary O-ring extending from the metal surfaces onto the phenolics of the radial OD portion of the joint. There was no pitting observed. There were no bondline separations observed on either the forward end of the throat inlet or the aft end of the -504 ring.

During nozzle Joint No. 3 disassembly inspections, a Helicoil in the nose inlet housing 90-degree threaded hole was found to be damaged. Another Helicoil at 100 degrees had approximately 1.5 coils raised above the face of the nose inlet housing. This damage occurred during joint disassembly operations. Refurbishment showed that the 90- and 100-degree aluminum threads of the nose inlet housing were damaged. Twinserts will be fitted in these two threaded holes.

STS-27A Throat-to-Forward Exit Cone (Joint No. 4)

A cross-sectioned view of the STS-27A throat/forward exit cone joint is presented in Figure 4.60. Photographs of the post-flight joint are shown in Figures 4.61 and 4.62.

The RTV backfill extended below the joint char line 360 degrees circumferentially. The RTV located on the radial ID portion of the joint below the char line was charred 360 degrees circumferentially. RTV completely filled the axial portion of the bondline and reached the high pressure side of the primary O-ring circumferentially, except from 43 to 50.5, and 97.5 to 132 degrees, where unfilled void areas were located. There were no blow paths to the void areas. The primary O-ring did not see pressure, and there was no evidence of blowby, erosion, or heat effect.

A small surface void in the EA913 NA adhesive was found adjacent to the steel forward exit cone housing. The void was centered at 286 degrees and measured 1.5 inch circumferentially, 0.020 inch deep axially, and 0.050 inch wide radially.

Rust corrosion was evident on both surfaces of the joint, extending from 31 to 97.5 degrees on the RTV surface. This corrosion was found to be starting at the metal to EA913 NA adhesive bondline of the throat assembly, and

appeared intermittently around the circumference. There was no pitting observed on the metal surfaces. White salt deposits were found on the phenolic radial ID portion of the joint intermittently around the circumference.

A continuous bondline separation approximately 0.01 inch wide radially was observed between the EA913 NA adhesive and the steel throat support housing 360 degrees circumferentially. There were no separations found between the adhesive and GCP, the GCP and CCP, or within the GCP or CCP.

STS-27A Fixed Housing-to-Bearing Aft End Ring (Joint No. 5)

A cross-sectioned view of the STS-27A aft end ring/fixed housing joint is presented in Figure 4.63. Photographs of the post-flight joint are shown in Figures 4.64 and 4.65.

RTV filled approximately 77 percent of the axial portion of the joint, but did not reach the high pressure side of the primary O-ring. There were no blow paths observed in the joint, and the primary O-ring did not see pressure. Small air pocket voids were observed within the RTV radial bondline intermittently around the circumference.

Rust corrosion was observed on the bearing aft end ring inboard of the secondary O-ring groove from 250 to 265 degrees. Three rust spots were found at the 265 degrees location on the secondary O-ring groove wall (low

pressure side). Rust corrosion was also found on the axial ID portion of the fixed housing intermittently around the circumference.

4.2 STS-27B (Right-Hand) Nozzle/Flex Bearing Observations

Overall erosion of the STS-27A forward nozzle assembly CCP ablative liner was smooth and uniform. Post-flight subassembly flow surface gaps are shown in Figure 4.66. Eroded chamfer edges were included in the flow surface bond gap measurements. Overall views of the nozzle are shown in Figure 4.67 through 4.74.

4.2.1 STS-27B Nozzle Components

Test objectives AB, AF, AG, AH, AI, AJ, AV, AW, BJ and BK are satisfied in this section.

STS-27B Aft Exit Cone Assembly

Overall views of the STS-27B aft exit cone fragment are shown in Figures 4.75 and 4.76.

The aft exit cone was severed aft of the compliance ring by the LSC. The nozzle severance system performance was nominal with no unusual tearing or breaking. The remaining aft exit cone fragment showed missing CCP liner 360 degrees circumferentially. Glass Cloth Phenolic (GCP) insulator plies were also torn from the severed end of the exit cone. The missing liner

and insulator exposed the aft 4 inches of the aluminum shell from approximately 120 to 290 degrees. There was no corrosion observed on the exposed metal. These are typical post-flight observations which occur during exit cone severance and at splashdown. GCP plies exposed by the missing liner showed no signs of heat effect. The EA946 adhesive bondline was also exposed on the aft 4 inches of the exit cone shell intermittently around the circumference. Voids were observed within the exposed adhesive (see Figure 4.77). The maximum void measured 2 inches circumferentially by 3 inches axially. Adhesive bondline voids are inherent to the aft exit cone bonding process and are an expected condition.

The polysulfide groove fill on the forward end of the aft exit cone showed no separations. Post-flight measurements of the polysulfide groove radial width (see Figure 4.78) show that the GCP insulator did not pull away from the aluminum shell during cooldown. The average post-flight radial width of the groove was 0.17 inch. The polysulfide appeared to shrink axially aft up to 0.09 inch (see Figure 4.79).

The aft exit cone forward end showed no separations within the GCP insulator. Sectioning of the insulator revealed separations within the GCP occurring intermittently along the exit cone length and around the circumference. These separations are typical observations and resulted from post-burn heat soak, liner shrinkage during cooldown, LSC ignition and/or splashdown.

Performance margins of safety could not be verified on the aft exit cone as a result of the loss of the CCP liner at LSC ignition and splashdown.

The aft exit cone shell forward face showed metal scratches intermittently around the circumference in line with the bolt holes (0.001 inch maximum axial depth). A metal ding on the OD corner of the secondary O-ring groove (0.08 inch circumferentially by 0.08 inch radially by 0.005 inch axially), and a scuff mark outboard of the secondary O-ring groove (0.12 inch circumferentially by 0.10 inch radially by 0.001 inch axially) were observed at 5 degrees. The scratches, ding and scuff mark occurred during disassembly. Refurbishment of the aft exit cone shell showed no Helicoil or aluminum thread damage resulting from the bent bolts observed in the aft exit cone field joint (see joint description in Section 4.2.2). The 45- and 135-degree actuator brackets showed only minor paint scratches due to disassembly operations. The compliance ring showed no damage.

STS-27B Forward Exit Cone Assembly

Overall views of the STS-27B forward exit cone are shown in Figures 4.71 and 4.72.

The forward exit cone showed missing CCP liner over the entire cone except on the aft 1 to 8 inches from 20 to 270 degrees. The missing liner exposed

the forward shear pins. This is a typical post-flight observation and occurs at splashdown and during DOP insertion. The GCP insulator exposed by the missing liner showed no signs of heat effect. The flow surface of the remaining liner showed the typical dimpled erosion pattern that has occurred on all flight and static test forward exit cones. The maximum radial depth of the dimpled erosion was 0.15 inch.

The aft end of the forward exit cone showed no cohesive separations or separations at the EA946 adhesive/steel housing, adhesive/GCP, and GCP/CCP interfaces.

Bondline separations on the forward end of the forward exit cone were noted between the steel housing and the EA946 adhesive intermittently around the circumference (see Figure 4.80). The maximum radial width of the separations was 0.005 inch. These separations are typical observations and result from post-burn heat soak and cooldown liner shrinkage. There were no other separations observed on the forward end.

Sectioned views of the remaining forward exit cone liner are shown in Figures 4.81 and 4.82.

Table 4.7 presents the STS-27B forward exit cone char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.15 shows the

locations of the measurement stations on the forward exit cone. All margins of safety were positive with a worst case of 0.12 at Station 32 (90 degrees).

The major splashdown snubber impact on the bearing aft end ring occurred over the 25-to-0-to-235 degree arc. Both the snubbers and aft end ring showed heavy paint scratches in this area (see Figures 4.83 and 4.84). One snubber (S/N 0001731) located at 235 degrees was displaced axially aft approximately 0.5 inch. The snubber segment retainer bolts were either sheared completely off or smashed from 270 to 340 degrees (see Figure 4.83). Impact of these bolts also left paint scratch marks on the aft end ring. The remainder of the bearing aft end ring circumference showed minor paint scratches indicating slight contact with the snubbers.

STS-27B Throat Assembly

Overall views of the STS-27B throat assembly (throat ring and throat inlet ring) are shown in Figures 4.84 through 4.86.

Erosion of the throat and throat inlet rings was smooth and uniform, with no wedgeouts observed. Popped-up charred CCP material was observed on the forward 1.5 inches of the throat inlet ring from 220 to 340 degrees. Sharp edges indicate this was a post-burn occurrence. Minor impact marks were observed on the aft 4 inches of the throat ring intermittently around the circumference.

The throat post-flight mean diameter was 55.910 inches (erosion rate of 8.31 mils/second based on an action time of 123.3 seconds). Nozzle post-burn throat diameters have ranged from 55.787 to 56.38 inches. The flow surface bondline gap between the throat and throat inlet rings was 0.10 inch and is typical of past static test and flight nozzles.

A continuous bondline separation between the EA913 NA adhesive and the steel throat support housing aft end was observed around the entire joint circumference (see Figure 4.87). The maximum radial width of the separation was 0.03 inch There were no cohesive separations or separations at the adhesive/GCP and GCP/CCP interfaces on the aft end. There were also no bondline separations observed on the throat inlet ring forward end.

Sectioned views of the throat and throat inlet ring liner and insulator are shown in Figures 4.88 and 4.89. Sectioning of the liner revealed CCP-to-GCP separations occurring intermittently along the throat inlet ring length and around the circumference. Separations were also observed within the GCP insulators of both rings. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.8 presents the STS-27B throat and throat inlet ring char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.19 shows the locations of the measurement stations on the throat assembly. All margins of safety were positive with a worst case of 0.04 at Station 8 (180 degrees).

STS-27B Nose Inlet Assembly

Overall views of the STS-27B nose inlet assembly are shown in Figures 4.73 and 4.74

The ply angle of the forward nose ring was checked and found to be of the RSRM design. The flow surface bondline gap between the forward nose (-503) ring and the aft inlet (-504) ring was 0.15 inch. The flow surface bondline gap between the -503 ring and nose cap was 0.04 inch. These post-fired measurements are typical of past static test and flight nozzles.

The -503 and -504 rings showed smooth erosion with no pockets or wash areas observed. Wedged out charred CCP material was observed on the forward 1.5 inches of the -504 ring from 73 to 100 degrees (see Figure 4.90). Popped-up charred CCP material was observed on the forward 1.3 inches of the -504 ring at 310 degrees and measured 4.5 inches circumferentially. A

small wash area was observed at the -503/-504 interface at approximately 230 degrees. The wash area measured 0.5 inch wide circumferentially by 1.5 inches long axially by 0.1 inch deep radially. Impact marks occurring after motor operation appeared on the -503 ring intermittently around the circumference. These marks most likely resulted from the loose aft and forward exit cone CCP material at splashdown.

The nose cap showed smooth erosion with no pockets or major washes observed. The aft 2 inches showed wedged-out and popped-up charred CCP material intermittently around the circumference (see Figure 4.91). Sharp edges indicate a post-burn occurrence time. No wedgeouts were observed on the forward end of the nose cap. The forward 1.5 feet on the nose cap OD surface showed typical minor washing (0.10 inch maximum radial depth).

There were no bondline separations observed on the -504 ring aft end or on the nose cap aft end.

Sectioned views of the nose cap, -503 and 504 rings liner and insulator are shown in Figures 4.92 through 4.95. Sectioning revealed CCP-to-GCP separations occurring intermittently along the lengths and around the circumferences of all three rings. Separations were also observed within the GCP insulators of the -503 and -504 rings . These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning

also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.9 presents the STS-27B -503 and -504 rings char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.27 shows the locations of the measurement stations on the -503 and -504 rings. All margins of safety were positive with a worst case of 0.13 at Stations 32 and 39 (180 degrees).

Table 4.10 presents the STS-27B nose cap char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.27 shows the locations of the measurement stations on the nose cap. All margins of safety were positive with a worst case of 0.01 at Station 24 (135 degrees).

STS-27B Cowl/Outer Boot Ring/Flex Boot

Overall views of the STS-27B cowl and OBR are shown in Figures 4.67 through 4.70. Close-up views are shown in Figures 4.96 and 4.97. The flow surface bondline gap between the cowl and nose cap was 0.10 inch. The flow surface bondline gap between the cowl and OBR was 0.10 inch. These post-burn gaps

are typical of past static test and flight nozzles. All cowl vent holes appeared plugged with slag on the OD of the ring.

Post-burn wedgeouts and popped-up charred CCP material were observed on the cowl ring aft 2.0 inches around the majority of the circumference. The ring was completely intact from 260 to 290 degrees, and from 350 to 0 to 36 degrees. Typical erratic erosion was observed on the intact portions of the cowl. The forward portion of the ring eroded a maximum of 0.15 inch more than on the aft portion of the ring (see Figure 4.96). This erratic erosion is a result of the low ply angle of the cowl ring and has been observed on the majority of flight and static test nozzles. Cross-ply cracking isolated in charred CCP material extended axially through the vent and shear pin holes.

Sectioned views of the cowl ring are shown in Figures 4.98 and 4.99. Minor ply-lift regions were observed within charred material on the forward half of the ring. Ply lifting has been observed on the majority of sectioned cowl rings and is believed to be a result of the low ply angle.

There were no bondline separations observed on the forward end of the cowl.

The structural backup outer boot ring was intact. The flow surfaces showed smooth erosion with no pockets or major washes. Post-burn wedgeouts and popped-up charred CCP material were observed on the forward 1.7 inches of the OBR intermittently around the circumference (see Figure 4.100).

Delaminations in the charred CCP on the aft tip were observed 360 degrees circumferentially. Charred CCP material on the aft tip (adjacent to the flex boot) fractured out and popped up over a majority of the circumference These are typical observations which have been observed on the majority of static test and flight nozzles.

Sectioned views of the OBR and flex boot are shown in Figures 4.101 through 4.104. Delaminations located in virgin material were observed at the OBR stiuctural back-up/overwrap interface (see Figure 4.102). The delaminations extended the entire axial length of the OBR at 90 degrees. There were no signs of heat effect within the delaminations.

The vulcanized axial bondline between the flex boot and the OBR showed separations intermittently around the circumference and along the axial length (see Figures 4.101, 4.103 and 4.104). There were no separations observed which extended the entire axial length of the bondline.

The cowl aft tip remained bonded to the flex boot around the entire circumference (see Figures 4.101 through 4.104). Small voids and cracks were observed within the EA913 NA adhesive. There were no signs of flow between the cowl and flex boot.

The axial bondline between the cowl and OBR showed cohesive and adhesive separations around the circumference, but showed no signs of flow. It is

believed that the separations in the axial bondline resulted from post-burn heat soak and cooldown liner shrinkage.

Table 4.11 presents the STS-27B cowl/outer boot ring char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.40 shows the locations of the measurement stations on the cowl and outer boot ring. All margins of safety were positive with a worst case of 0.24 at Station 12 (140 degrees).

The cavity side of the flex boot showed no evidence of flow or erosion. It was uniformly sooted and charred (see Figure 4.105) and appeared typical of previous flight and static test nozzles. A minimum of 3.6 NBR plies remained around the flex boot circumference following the flight (see Figures 4.101 through 4.104). Figure 4.106 presents the flex boot material affected depth per circumferential location, along with the performance margins of safety. The worst-case performance margin of safety was 0.39 and occurred at 320 degrees.

STS-27B Fixed Housing Assembly

Overall views of the STS-27B fixed housing assembly are shown in Figures 4.67 through 4.70

The fixed housing insulation erosion was smooth and uniform. Post-burn wedgeouts of charred CCP material were observed on the forward 2.0 inches intermittently around the circumference (see Figure 4.107). The maximum radial depth was 0.4 inch. One wedgeout from 145 to 162 degrees contained slag. Sectioning the liner at this location showed that the char line did not follow the contour of the wedgeout, indicating a post-burn occurrence. There was no heat effect to the GCP insulator observed.

There were no bondline separations observed on the forward or aft ends of the fixed housing assembly.

Sectioned views of the fixed housing liner and insulator are shown in Figures 4.108 and 4.109. Sectioning of the liner revealed CCP-to-GCP separations occurring intermittently along the length and around the circumference. Separations within the GCP insulator were also observed. These separations are typical observations and resulted from post-burn heat soak and cooldown liner shrinkage, and/or from washout and sectioning operations. Sectioning also revealed surface delaminations extending into virgin CCP material. There was no evidence of heat effect within the virgin material.

Table 4.12 presents the STS-27B fixed housing insulation char and erosion data and performance margins of safety. The margins of safety in this table were based on measured erosion, corresponding measured char adjusted to the end of action time, and RSRM minimum liner thicknesses. Figure 4.45 shows the locations of the measurement stations on the fixed housing insulation. All margins of safety were positive with a worst case of 0.55 at Station 11 (180 degrees).

The alignment pin (spring pin) at 91.8 degrees on the forward face of the fixed housing aft flange exhibited an axial crack 0.008 inch wide along the entire length of the pin. This observation is discussed further in Section 6.2 of this report.

STS-27B Bearing Protector

The bearing protector was sooted along the entire length and circumference (see Figures 4.110 and 4.111). Heavier soot and erosion were observed in line with the cowl ring vent holes at the thickened portion of the bearing protector. Erosion depths at these locations are presented in Figure 4.112 There was no evidence of heat effect on the ID surface of the bearing protector.

STS-27B Flex Bearing

The STS-27B flex bearing was previously used on the SRM-10A and -19A flights. Overall flex bearing performance during the flight was acceptable. The bearing showed no damage and no indications of exposure to heating. The post-flight bearing passed acceptance testing. Post-flight measurements showed an increase in Pad #2 unbond area. The increase, however, was attributed to more thorough inspection techniques. The significant unbond area of Pad #2 did not increase.

During post-flight inspection, six indentations were noticed on the flex bearing pads #7 and #8 (see Figure 4.113). The locations and sizes of the indentations are summarized in Table 4.13. It was initially believed that the indentations might have resulted from hot gas impingement through the cowl vent holes. Closer inspection, however, showed that the Chemlock coating on the rubber had not been heat affected. In addition, the bearing protector did not burn through. The flex bearing rubber pad surfaces were wiped, and an analysis was conducted on the samples taken. No indications of flow were found. The indentations are believed to have resulted from the rubber taking on a perminent set while an object or objects inadvertently rested on the bearing assembly. It should be noted that the indentations do meet the acceptable surface defect criteria specified in STW3-3497A paragraph 3.2.2.6.1, and that the flex bearing assembly is an acceptable part.

The bearing aft end ring showed major paint scratches occurring from 25 to 0 to 235 degrees, due to snubber impact during splashdown. Impact of the snubber retainer bolts also left paint scratch marks on the aft end ring (see Figure 4.84). The remainder of the bearing aft end ring circumference showed minor paint scratches indicating slight contact with the snubbers.

4.2.2 STS-27B Nozzle Joints

Descriptions of the five STS-27B nozzle joints follows. The joint flow surface gap openings between each nozzle subassembly are summarized in Figure 4.66. All gaps were typical of previous static test and flight nozzles.

<u>STS-27B Aft Exit Cone-to-Forward Exit Cone (Joint No. 1)</u>

A cross-sectioned view of the STS-27B aft exit cone/forward exit cone field joint is presented in Figure 4.114. Photographs of the post-flight joint are shown in Figures 4.115 and 4.116.

The backfilled RTV extended below the joint char line 360 degrees circumferentially, except possibly at 295 degrees. The RTV did not extend to the axial portion of the bondline at this location. The CCP liner was missing from the forward and aft exit cones at 295 degrees, making it

impossible to determine if the RTV extended below the char line. Pressure may have reached the primary O-ring at this location, but there was no evidence of primary O-ring blowby, erosion or heat effect. RTV reached the high pressure side of the primary O-ring groove from 0 to 30, 48.75 to 67.5, 82, 88, 90 to 92, 99 to 104, 118 to 126, 130 to 132, 135 to 236, 238 to 275 and 310 to 0 degrees. One unfilled void area located on the radial ID and axial portions of the bondline was observed at 237 degrees. There was no blowpath extending to the unfilled void area.

Examination of the joint showed black and white corrosion appearing between the primary and secondary O-rings, and outboard of the secondary O-ring intermittently around the circumference. The black corrosion is the beginning stage of the aluminum oxide. The corrosion was less than that observed on the STS-26 (LH) and (RH) joints. There was no pitting observed. A white colored residue was observed on the high pressure side of the primary O-ring groove intermittently around the circumference (see Figure 4.117). It is believed that the residue is grease mixed with sea water.

A white rubbery substance was observed on the aft end of the forward exit cone on the EA946 adhesive bondline, intermittently around the circumference similar to that observed on the (LH) forward exit cone. The substance was flexible when stretched and adhered to the aft surface. Lab analysis showed the substance to be tape adhesive. This observation is discussed further in Section 6.1 of this report.

Removal of the aft exit cone field joint bolts showed some bent bolts and damaged bolt threads. Approximately 12 bolts removed from the 0 to 90 degrees quadrant were bent (see Figure 4.118). A preliminary visual examination of the helicoils in the aft exit cone shell forward end revealed no visible damage. There was also no visible damage observed in the forward exit cone housing aft end through holes. Closer inspection information will be gathered during Clearfield H-7 refurbishment.

The aft exit cone shell forward face showed metal scratches intermittently around the circumference in line with the bolt holes (0.001 maximum axial depth). A metal ding on the OD corner of the secondary O-ring groove (0.08 inch circumferentially by 0.08 inch radially by 0.005 inch axially), and a scuff mark outboard of the secondary O-ring groove (0.12 inch circumferentially by 0.10 inch radially by 0.001 inch axially) were observed at 5 degrees. The scratches, ding and scuff mark occurred during disassembly. The 45- and 135-degree actuator brackets showed only minor paint chipping and scratching due to disassembly operations. The compliance ring showed no damage.

The forward exit cone housing aft flange 91.8-degree locator pin hole showed no visible damage caused by the alignment pin during aft exit cone demate.

STS-27B Nose Inlet-to-Bearing Forward End Ring-to-Cowl (Joint No. 2)

A cross-sectioned view of the STS-27B nose inlet/forward end ring/cowl joint is presented in Figure 4.119. Photographs of the post-flight joint are shown in Figures 4.120 through 4.123.

The RTV extended below the joint char line and filled the radial OD portion of the joint 360 degrees circumferentially. RTV extended to the nose inlet housing intermittently around the circumference. No RTV extended to the primary O-ring. The radial bondline between the nose cap and cowl showed RTV mixed with the EA913 NA adhesive intermittently around the circumference. The adhesive, which extruded from the cowl housing bondline, was typically sandwiched between two layers of RTV. There were no distinct blow paths in the joint, although soot was observed on the bondline radial OD intermittently around the circumference. The lack of adhesion between the RTV and adhesive allowed soot to enter the joint. Soot extended to the joint axial bolt holes intermittently around the circumference. Soot was also observed to the primary O-ring groove at three locations, but it is believed that water entering the joint at disassembly caused this. Light soot was also observed between the cowl ring and the bearing forward end ring. The primary O-ring saw pressure, but showed no signs of blow by, erosion or heat effect.

Paint on the bearing forward end ring OD flange surface was chipped off in various spots, but was not heat affected. Minor rust spots were noted in areas where the paint was chipped off. White corrosion was observed on the cowl housing flange forward end, ID surface and aft end. There was no pitting observed. Minor corrosion was also noted along the cowl housing axial ID surface in line with the bearing protector forward end ring. The nose inlet housing aft end and the bearing forward end ring flange forward and aft ends showed no corrosion.

Minor paint and metal scratches, due to cowl segment removal, were observed on the inside surfaces of the cowl housing. Minor scratches, due to disassembly jacking screws, were also observed on the nose inlet housing aft end. Burnish marks were observed on the nose inlet housing secondary O-ring sealing surface in line with the axial bolt holes of the joint. The marks resulted from the bearing forward end ring rubbing the sealing surface during disassembly. Further inspection during refurbishment is required to determine if the sealing surface was damaged.

STS-27B Nose Inlet-to-Throat (Joint No. 3)

A cross-sectioned view of the STS-27B nose inlet/throat joint is presented in Figure 4.124. Photographs of the post-flight joint are shown in Figures 4.125 through 4.126.

The RTV backfill extended below the joint char line and completely filled the radial ID portion of the joint 360 degrees circumferentially. RTV also extended onto the radial OD portion of the bondline from 270 to 300 degrees, but did not reach the primary O-ring groove. There were no distinct blow paths in the joint. Soot however was observed within the RTV and within the unfilled area between the RTV and housing bondlines from 120 to 210 degrees. Pressure entered the joint by way of a cohesive separation within the RTV over this degree arc. The GCP insulators at the joint interface showed no heat effect. The primary O-ring saw pressure but showed no evidence of blow by, erosion or heat effect.

Minor surface corrosion was observed on the aft (-504) end of the nose inlet housing inboard of the primary O-ring, but no pitting was observed. The forward end of the throat housing also showed minor corrosion inboard of the primary O-ring.

STS-27B Throat-to-Forward Exit Cone (Joint No. 4)

A cross-sectioned view of the STS-27B throat/forward exit cone joint is presented in Figure 4.127. Photographs of the post-flight joint are shown in Figures 4.128 and 4.129.

The RTV backfill extended below the joint char line and completely filled the radial ID and axial portions of the joint 360 degrees circumferentially. RTV reached the high pressure side of the primary O-ring groove at 15, 40 to 70, 85, 95 to 100, 150 to 180, 195 to 280, 292 to 330 and 335 degrees. There were no blow paths or excess grease observed in the joint. The primary O-ring did not see pressure. The GCP insulators in the joint also showed no signs of heat effect.

Rust corrosion was observed on the throat housing aft end inboard of the primary O-ring (high pressure side) intermittently around the circumference. There was no corrosion observed on the forward exit cone forward end.

STS-27B Fixed Housing-to-Bearing Aft End Ring (Joint No. 5)

A cross-sectioned view of the STS-27B aft exit cone/forward exit cone field joint is presented in Figure 4.130. Photographs of the post-flight joint are shown in Figures 4.131 and 4.132.

RTV filled all of the radial portion and approximately 12 percent of the axial portion of the joint bondline. RTV did not reach the high pressure side of the primary O-ring groove. There were no blow paths observed in the joint and the primary O-ring did not see pressure. Small voids isolated within the RTV on the radial portion of the joint bondline were observed intermittently around the circumference (see Figure 4.133).

Rust corrosion was found on the bearing aft end ring inboard of the secondary O-ring groove (low pressure side) intermittently around the circumference. Minor pitting was observed.

4.3 Thermal/Structural Instrumentation

Strain and temperature data were measured to verify the nozzle structural integrity during flight. Measuring strain and temperature data provide a valid oppurtunity to measure nozzle response under flight loads. Due to the severe environment on phenolic nozzle components during flight, strain and temperature data is currently being gathered on the cool side metal parts.

Instrumentation included 18 biaxial strain gages and 13 thermocouples on each nozzle. Table 4.14 lists all nozzle instrumentation gage numbers, gage types, general locations, and stations. All gages located at the same axial location are assigned a location number. These numbers represent the same locations specified on previous static motor tests. Missing location numbers imply that there were no gages installed at those locations. Figure 4.134 shows the locations of the strain gages. The locations of the thermocouples are shown on Figure 4.135.

The structural integrity of the nozzle was verified in that the instrumentation data demonstrated positive margins of safety at all locations measured. In general, all strain gage data correlated very well with the predicted strains from analysis models as well as data obtained from static test motors. Nozzle strains tended to be low (less than 2000 microinch/inch), and hoop strains followed the pressure trace.

Measured strain results were compared with a course grid TASS Finite Element model. Figures 4.136 through 4.173 show the correlation between each strain gage and the predicted strain at each location. Figures 4.174 through 4.182 show the thermocouple readings for each location. Temperatures tended to be constant throughout the flight and remained in an acceptable range.

5.0 DISCREPANCY REPORTS AND PROCESS DEPARTURES

The STS-27 discrepancy reports (DRs) and process departures (PDs) reviewed by the Morton Thiokol senior material review board (MRB) are summarized in Appendix A. These DRs and PDs were presented in the STS-27 Redesigned Solid Rocket Motor Acceptance Review Level III (TWR-18533 Rev A). Performance of the discrepant areas is discussed below.

5.1 STS-27A (Left-Hand) Nozzle

DR 172753-01, -02 and -03 were written against out of tolerance bondgaps between the nose cap and cowl ring. Post-flight inspections of the nose/bearing forward end ring/cowl Joint No. 2 revealed no anomalies (see Section 4.1.2).

DR 153750-01 concerned a Low Density Indication (LDI) within the aft exit cone GCP insulator from 51 to 54 degrees. The LDI was located approximately 5.6 inches aft of the forward end of the cone. Performance of the aft exit cone was nominal. Post-flight inspection showed that the GCP insulator inner plies were torn off at splashdown. The LDI could not be examined as a result.

5.2 STS-27B (Right-Hand) Nozzle

DR 127756-01 concerned the STS-27B flex bearing Pad #2 exceeding allowable unbond area. The flex bearing performed as expected during the flight and

showed no external signs of damage after disassembly. Post-flight measurements showed an increase in Pad #2 unbond area. The increase, however, was attributed to more thorough inspection techniques. The significant unbond area of Pad #2 did not increase.

DR 162641-01 and -02 were written against an LDI located in the fixed housing GCP insulator aft end at 210 degrees. Post-flight inspection following nozzle-to-case joint disassembly showed no separations on the aft end of the fixed housing insulator, at the LDI location. Sectioning showed delaminations in the area of the LDI. It is believed that the delaminations resulted from post-burn washout and sectioning operations.

DR 152184-01 was written against approximately 30 LDIs located at the throat ring CCP/GCP interface, intermittently around the circumference. The LDIs extended from the aft end of the part to 4.72 inches aft of the ring forward end. Post-flight sectioning of the throat ring revealed no separations between the CCP liner and the GCP insulator.

DR 153702-01 concerned approximately 139 LDIs located at the aft exit cone CCP/GCP interface, aft of the compliance ring. Videos showed that the aft exit cone performed nominally. Severance of the exit cone aft of the compliance ring prevented post-flight inspection of the LDIs.

6.0 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS AND RPRB ASSESSMENT

The NCPT reviewed all observations documented in this report. The team initially classified eight observations as potential anomalies. Three of the potential anomalies were reduced to observations, and five were elevated to minor anomalies. The NCPT presented the recommendations to the RPRB on January 25, March 8, and April 5, 1989 (see Appendix B). The five minor anomalies were accepted by the RPRB. Descriptions of the anomalies and specific actions assigned are discussed below.

6.1 STS-27A (Left-Hand) Nozzle

The first minor anomaly was a white rubbery substance that was observed on the forward exit cone EA946 adhesive bondline aft end. The white rubbery substance was observed intermittently around the circumference on both the right-hand and left-hand nozzles. Lab analysis showed the substance to be tape adhesive. MTI Wasatch places tape on the forward exit cone phenolics aft end to protect the phenolics from grease. KSC receives the aft segment/nozzle assembly with the tape on the forward exit cone. The KSC OMI has an inspection step requiring personnel to remove the tape, clean and inspect the forward exit cone aft phenolic and metal surfaces. The NCPT classified this as a minor anomaly because it was significant departure from our data base, and it requires corrective action but has no impact on motor performance or program schedule. The tape adhesive does

not interfere with the primary O-ring seal. The NCPT recommended that the KSC LSS office review assembly inspections and procedures and make changes to prevent recurrence. The RPRB agreed with the recommended classification and corrective action.

6.2 STS-27B (Right-Hand) Nozzle

The second minor anomaly was a metal ding on the OD corner of the secondary O-ring groove of the STS-27B aft exit cone shell. The ding was located at 5 degrees and measured 0.080 inch circumferentially by 0.005 inch axially by 0.080 inch radially. The metal ding occurred during transportation to the hanger floor or during break over. The NCPT classified this as a minor anomaly because it requires corrective action, but has no impact on motor performance or program schedule. Additional justification was that disassembly operations could cause damage preventing reuse of hardware if the damage occurred on the sealing surface of the O-ring. The NCPT recommended that KSC SPC personnel review disassembly procedures and make changes to prevent recurrence. The RPRB agreed with the recommended classification and corrective action.

The third minor anomaly concerned bent bolts observed in the STS-27B (right-hand) aft exit cone field joint in the 0-to-90-degree quadrant due to high splashdown loads. The aft exit cone shell and the forward exit cone housing showed no visible damage. The NCPT recommended classifying

the bent bolts as a minor anomaly because they are a significant departure from our data base. The NCPT recommended reviewing instrumentation data to verify the damage occurred at splashdown, analyzing the bent bolts to see if properties meet MTI specifications, reviewing vendor certifications on the bolts to see if the vendor met MTI specifications, and adding bent bolts to the KSC Nozzle PEEL Document (TWR-18680 Vol 5) as a "reportable" condition. The RPRB agreed with the recommended actions, but decided to wait on the classification of the anomaly until refurbishment data was obtained on the forward and aft exit cone hardware. This anomaly was represented at the STS-29 RPRB meeting (5 April, 1989) when the refurbishment data was available. The forward and aft exit cone hardware showed no damage, and the RPRB then agreed with the minor anomaly classification.

The fourth minor anomaly was a cracked alignment pin observed on the STS-27B (right-hand) fixed housing aft end (91.8 degrees). The crack extended the length of the pin. The NCPT initially recommended classifying the cracked pin as an observation based on the justification that this is not a flight safety or hardware reuse issue. Recommended corrective actions were to continue inspecting for future occurrences, add limits to the KSC Nozzle PEEL Document (TWR-18680 Vol 5) if observations continue, and add an inspection point to planning to inspect the alignment pin after being installed in the fixed housing. The RPRB agreed with these and assigned an additional action to have Metallurgy examine the cracked pin,

and to report back before classifying this as an observation. The NCPT represented this anomaly in the STS-29 RPRB meeting (5 April, 1989) as a minor anomaly based on the justification that it was a departure from our data base and it is not a hardware reuse issue. The NCPT recommended an additional action to add an inspection point in existing planning to inspect the alignment pin during nozzle/case joint assembly. The pin should be inspected for possible contact with the aft dome and fracture. The RPRB stated that this inspection point shall clearly define what procedures would be followed if alignment pin fracturing was observed during assembly. Also, the NCPT recommended incorporating accept/reject limits into the KSC Nozzle PEEL Document (TWR-18680 Vol 5) as a result of this being observed again on the STS-29A nozzle. The RPRB accepted the minor anomaly classification and the additional actions.

The fifth minor anomaly was sheared off snubber retainer bolt heads (13 total) on the STS-27B nozzle. The bolts were sheared off during bearing aft end ring impact at splashdown. The bearing aft end ring showed no metal damage, only paint scratches. The forward exit cone housing showed no visible damage following removal of the sheared bolts and snubber retainers. This had not been observed on an RSRM nozzle to date. STS-1 and 2 nozzles showed similar damage occurring at splashdown. The NCPT recommended classifying this as a minor anomaly if there was no bearing damage. The justification used was that the sheared bolts were a departure from our RSRM data base. The NCPT recommended inspecting for future

occurrences and adding accept/reject limits to the Nozzle KSC PEEL Document (TWR-18680 Vol 5) if observations continue. The RPRB accepted the NCPT recommendations. Post-flight bearing acceptance testing showed no damage. This was therefore classified as minor anomaly.

During the STS-27B (right-hand) aft exit cone field joint inspection, a NASA inspector felt that the backfill condition was anomalous. The initiated squawk was signed in non-concurrence by both MTI and NASA engineers. The RTV backfill did not extend to the primary O-ring groove 360 degrees circumferentially. There was no blowby, erosion or heat effect observed to the primary O-ring. The RTV backfill depth observed on the STS-27B aft exit cone field joint was typical of past flight and static test nozzle joints. The NCPT recommended classifying this as an observation based on the justification that this was not a flight issue. The design goal of the nozzle joint RTV backfills is to fill below the joint char line. The STS-27B aft exit cone field joint showed RTV filling below the joint char line 360 degrees circumferentially. The NCPT recommended adding RTV accept/reject limits to the Nozzle KSC PEEL Document (TWR-18680 Vol 5). The RPRB agreed with the recommended observation classification and action.

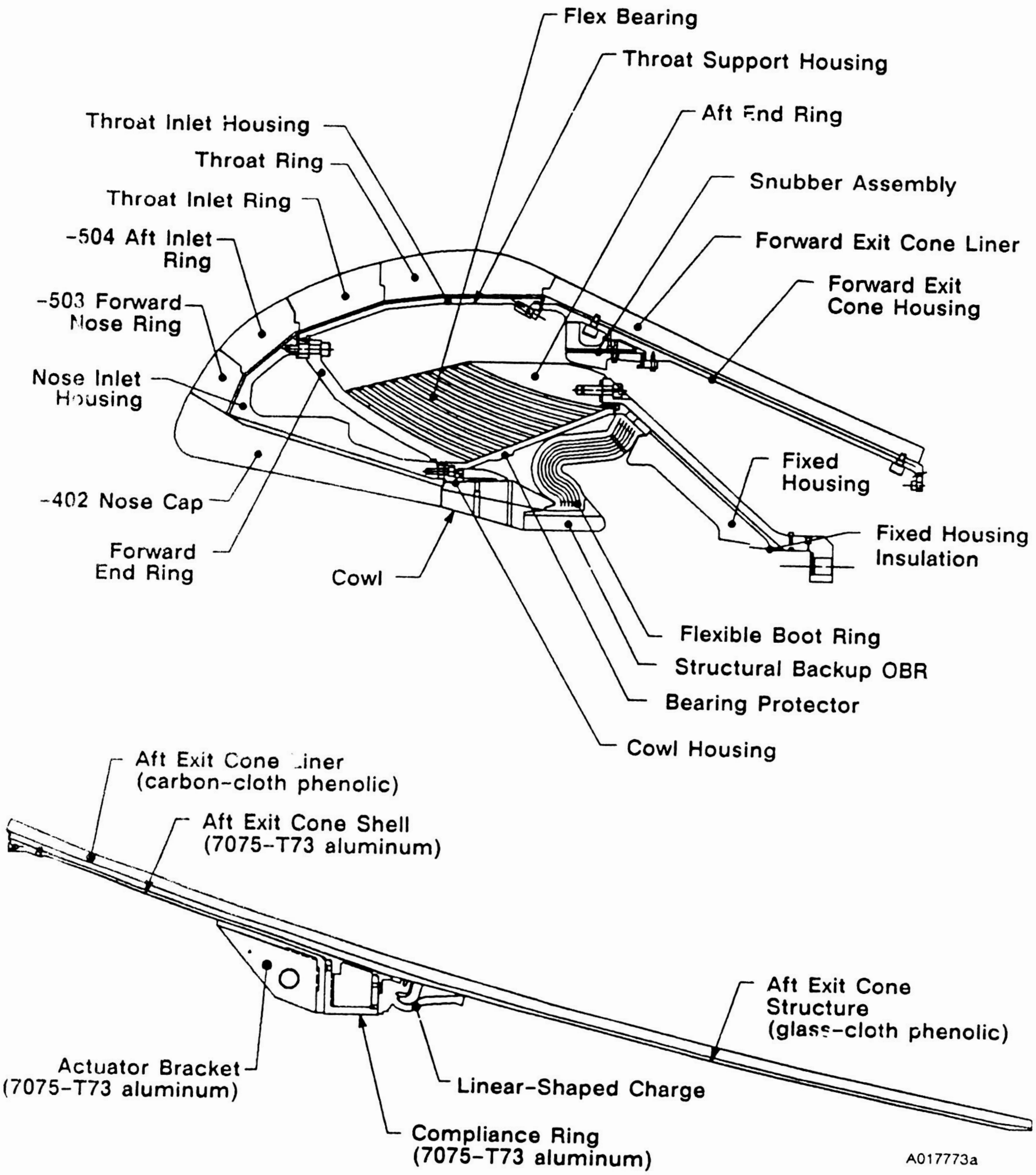


Figure 1 STS-27 Nozzle Components

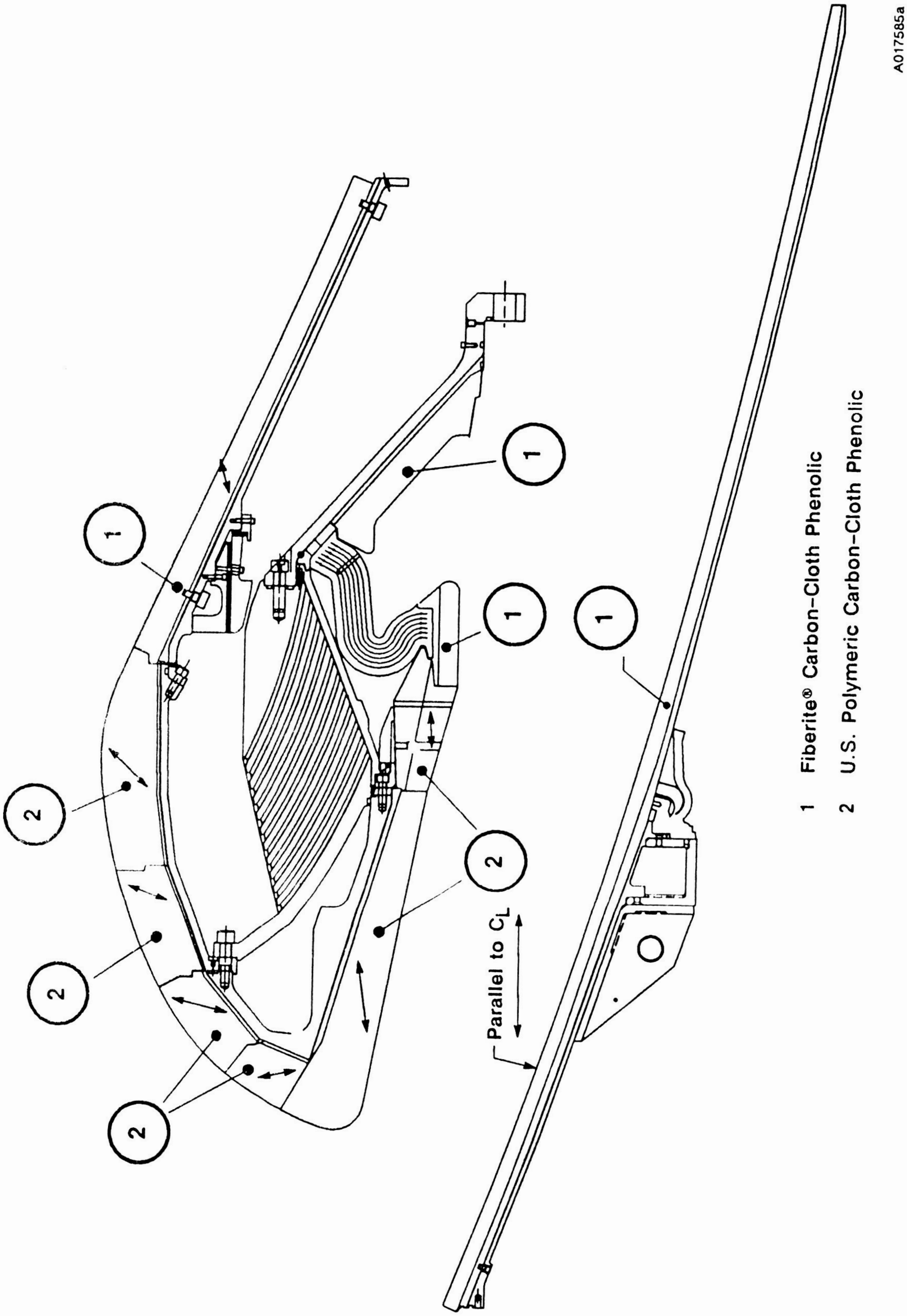
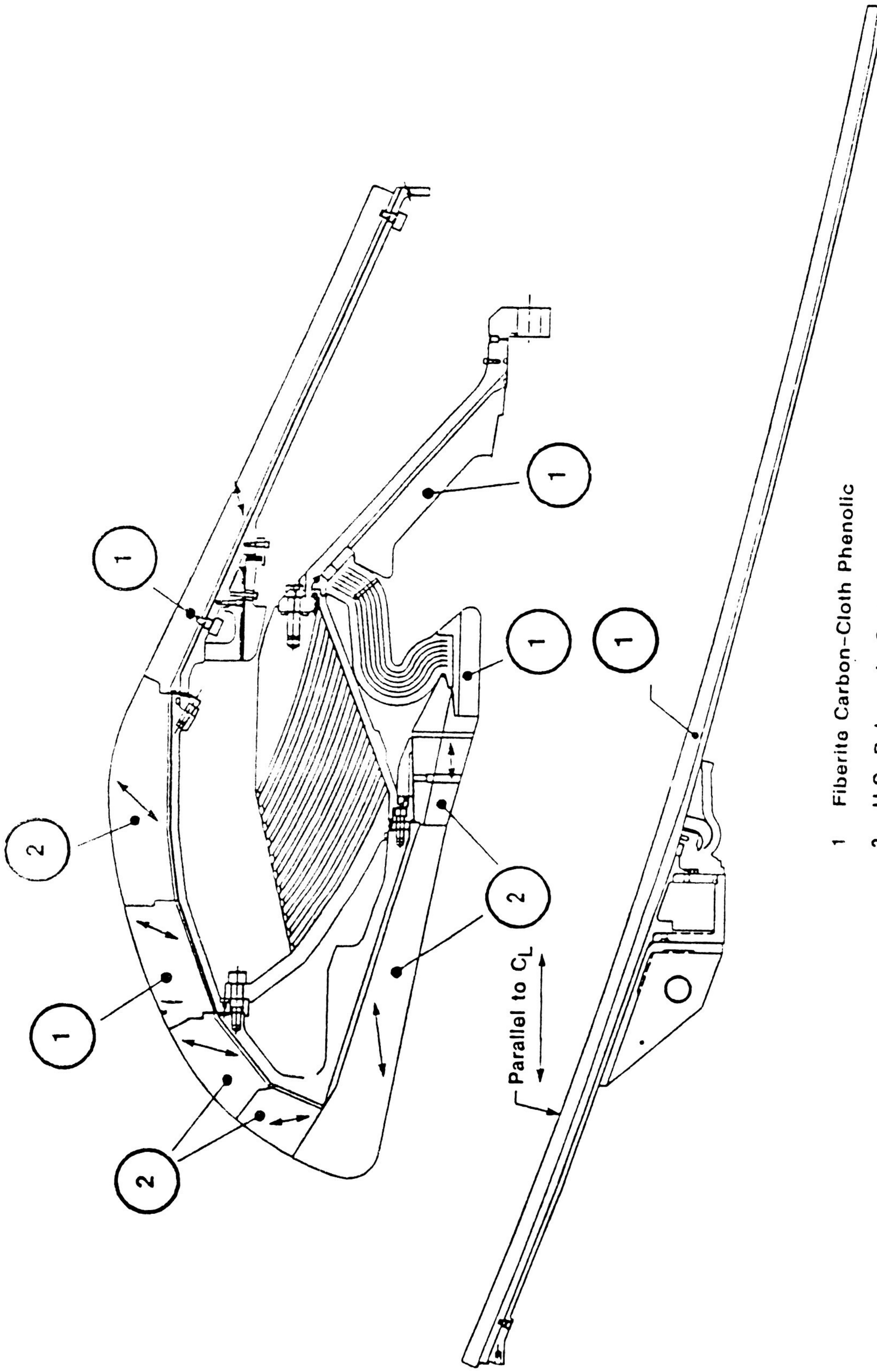


Figure 2a STS-27A Nozzle Material



1 Fiberite Carbon-Cloth Phenolic
2 U.S. Polymeric Carbon-Cloth Phenolic

Figure 2b STS-27B Nozzle Material

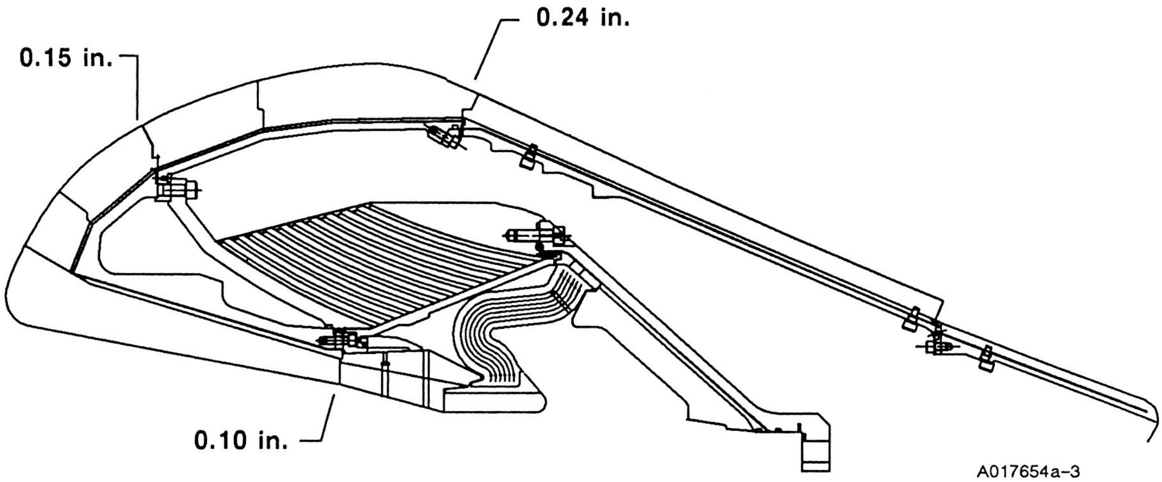


Figure 4.1 STS-27A Joint Flow Surface Gap Openings

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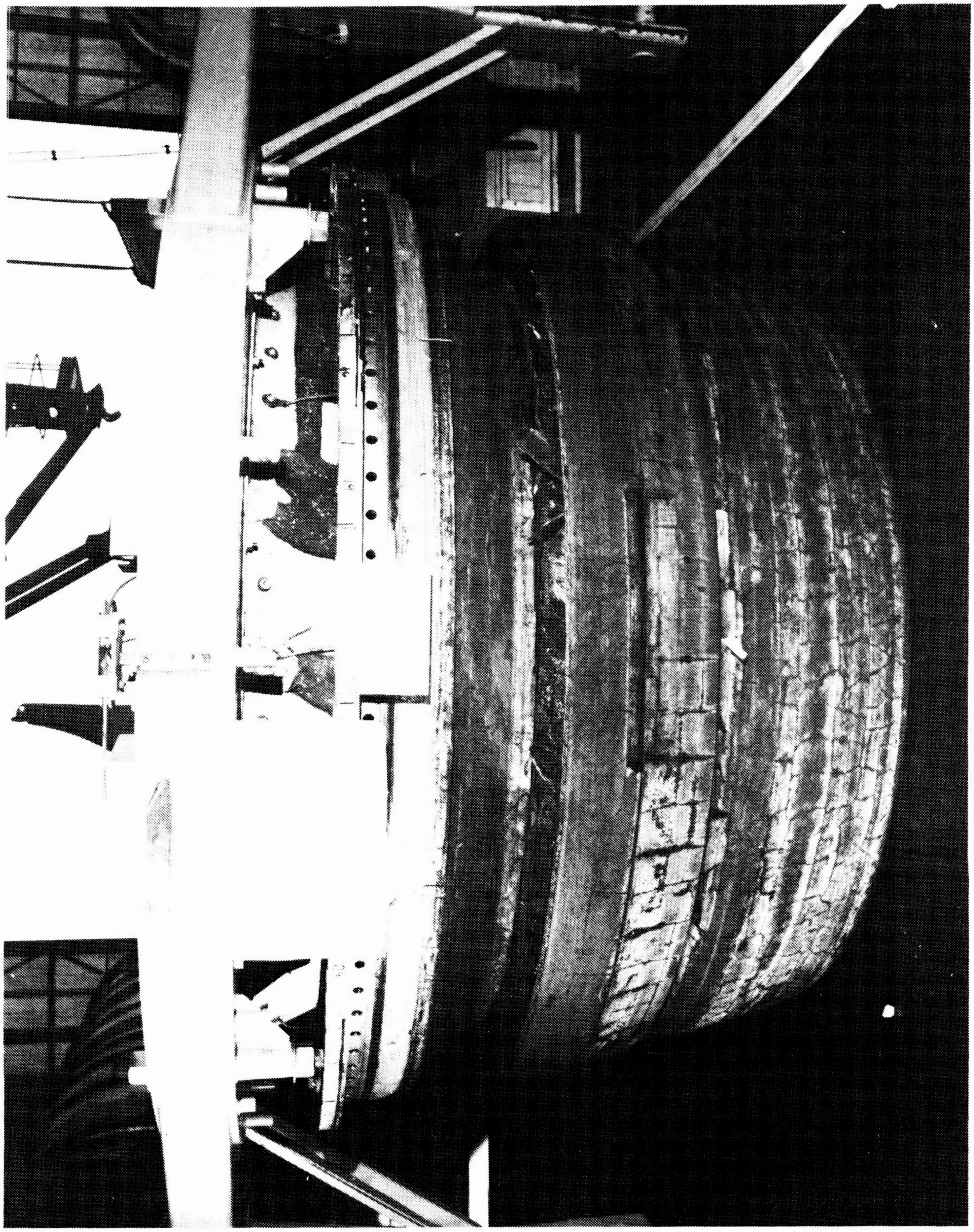

Figure 4.2 STS-27A Nozzle Overall View (90 degrees)

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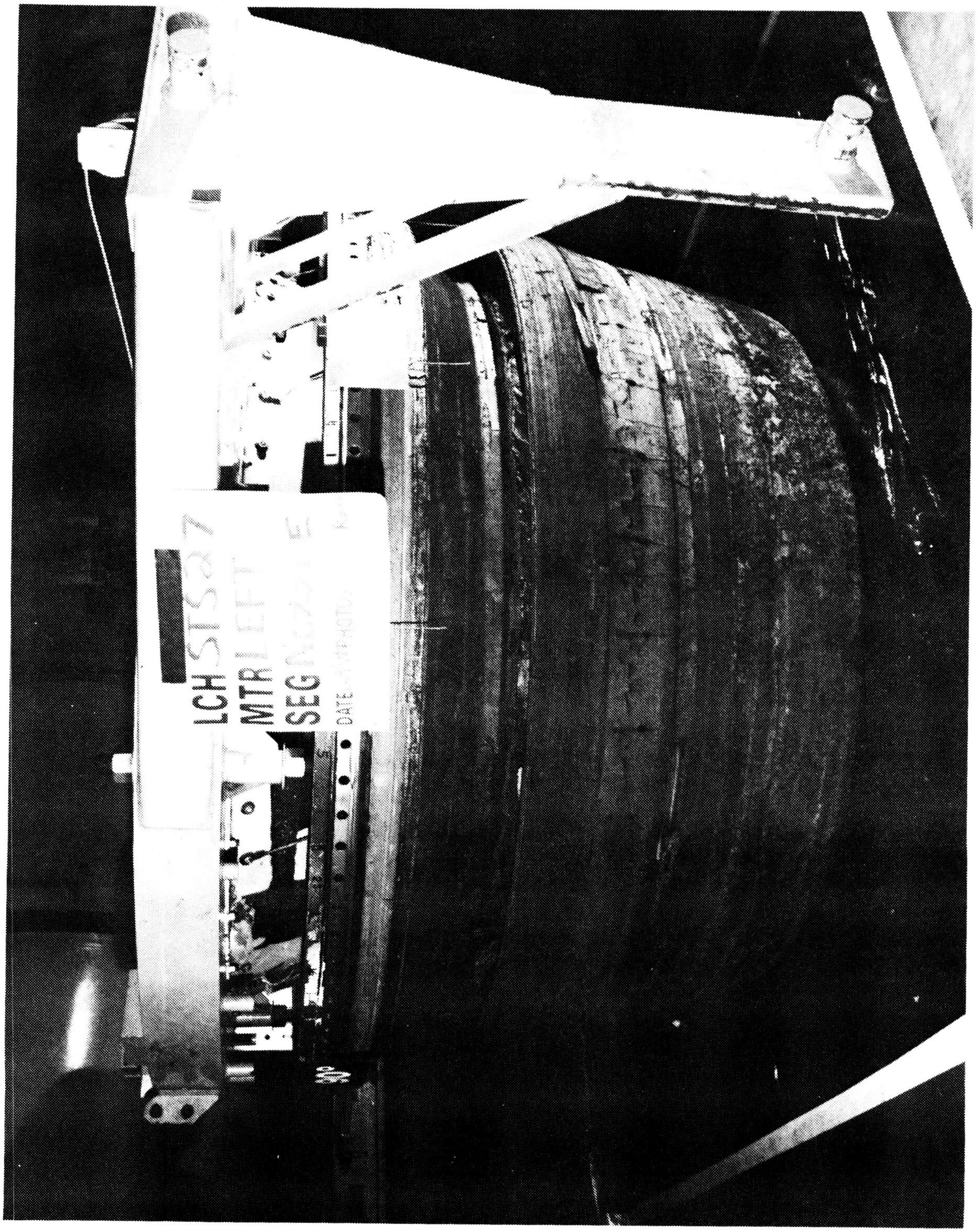

Figure 4.3 STS-27A Nozzle Overall View (90-180 degrees)

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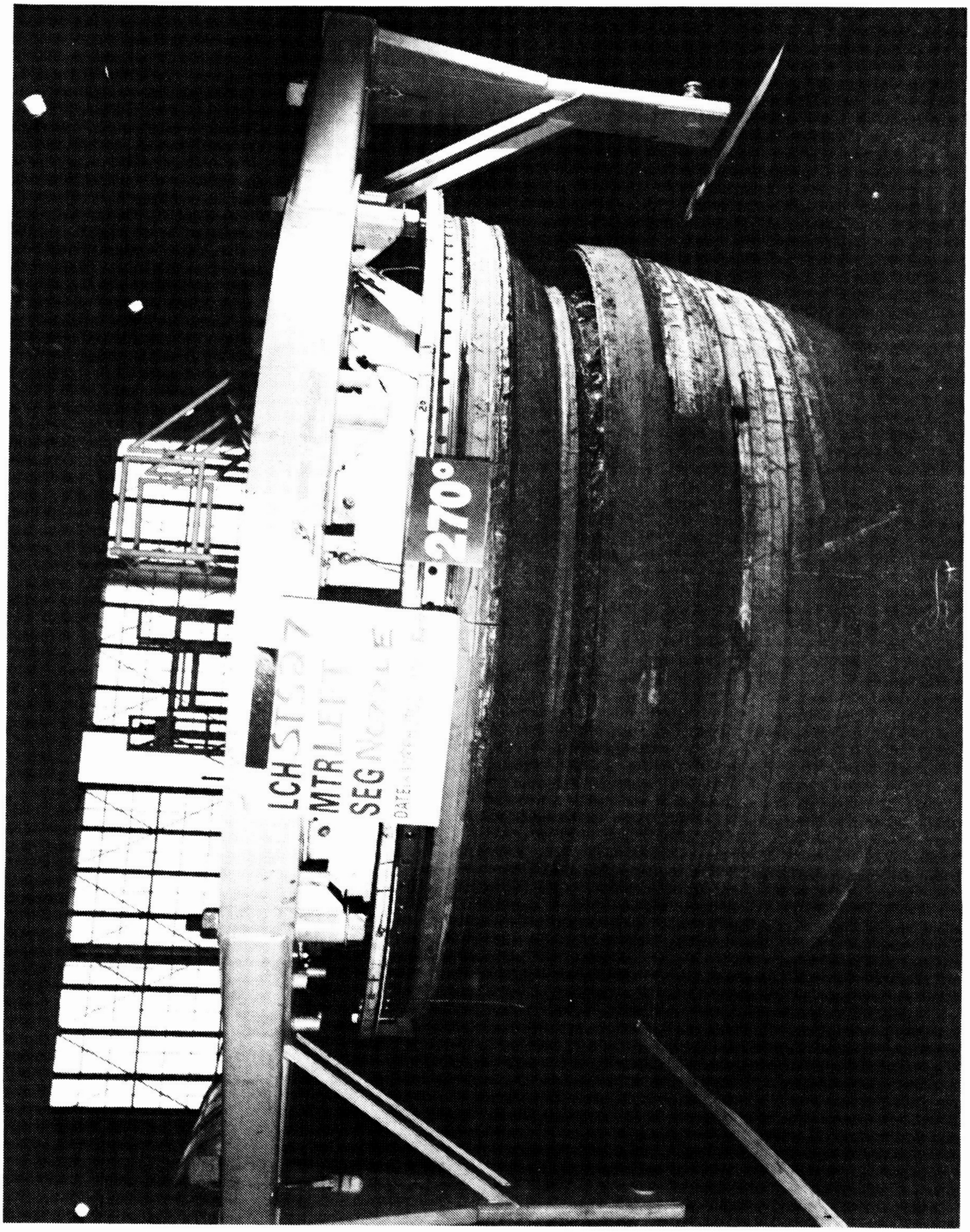

Figure 4.4 STS-27A Nozzle Overall View (270 degrees)

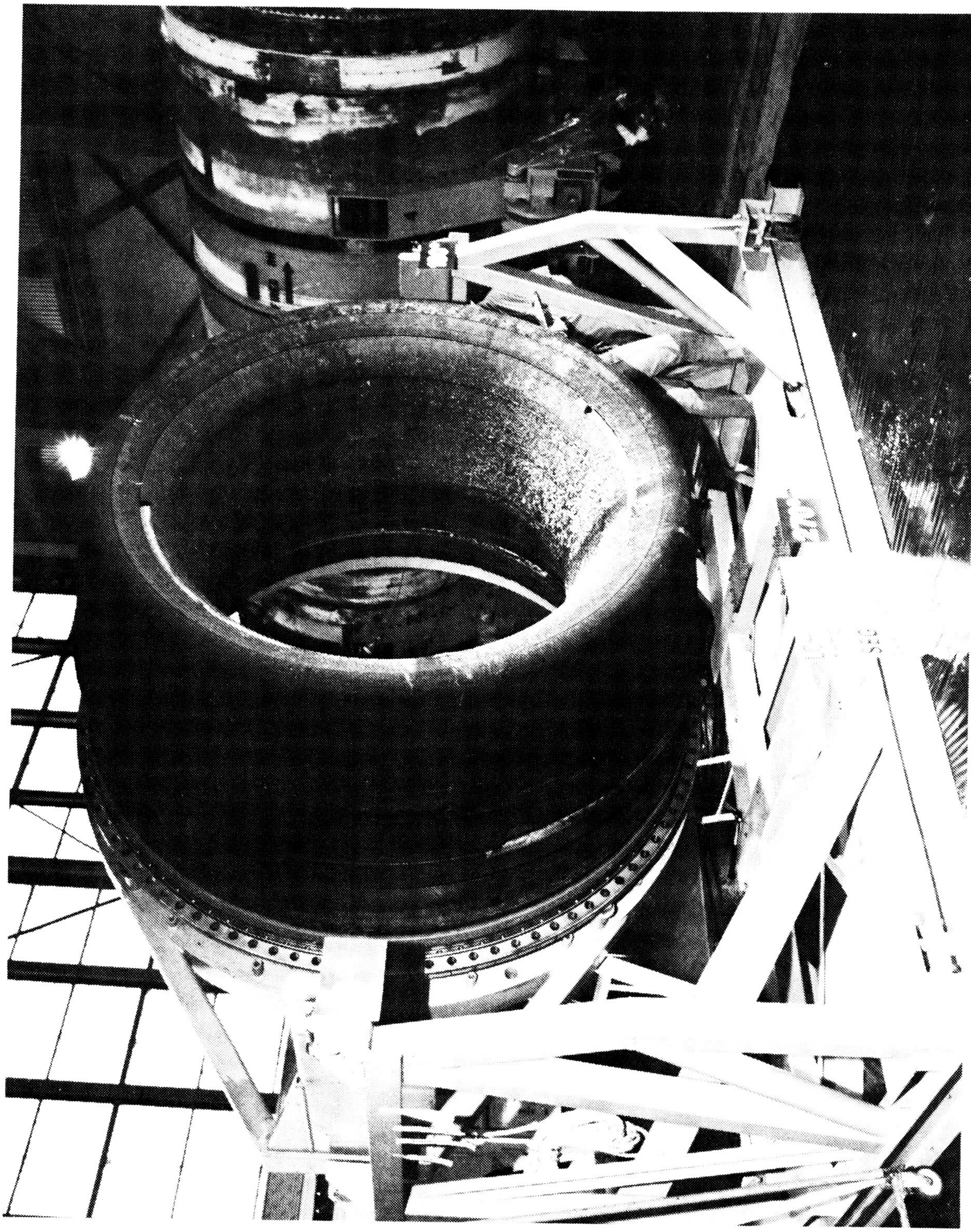

Figure 4.5 STS-27A Nozzle Overall View

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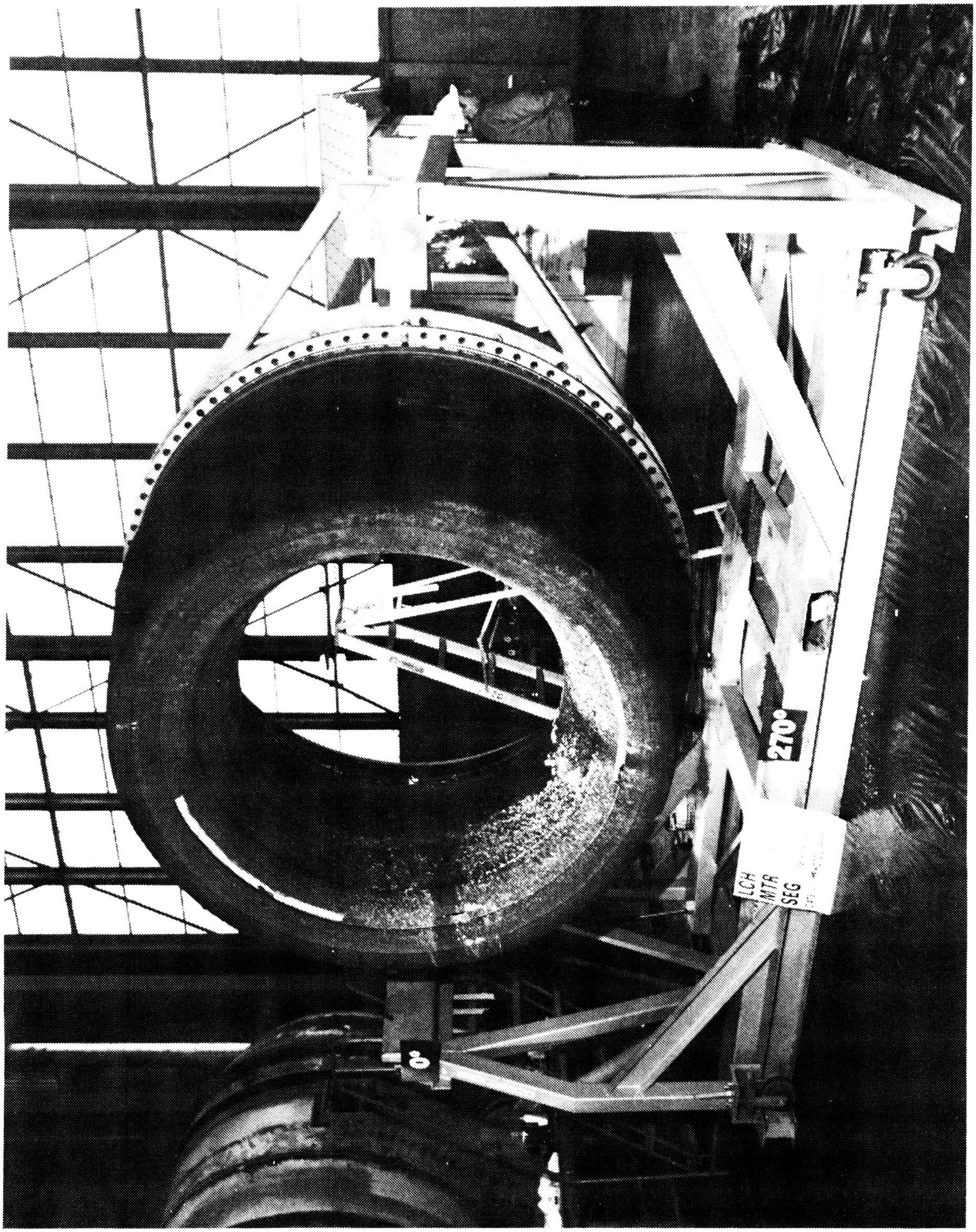

Figure 4.6 STS-27A Nozzle Overall View

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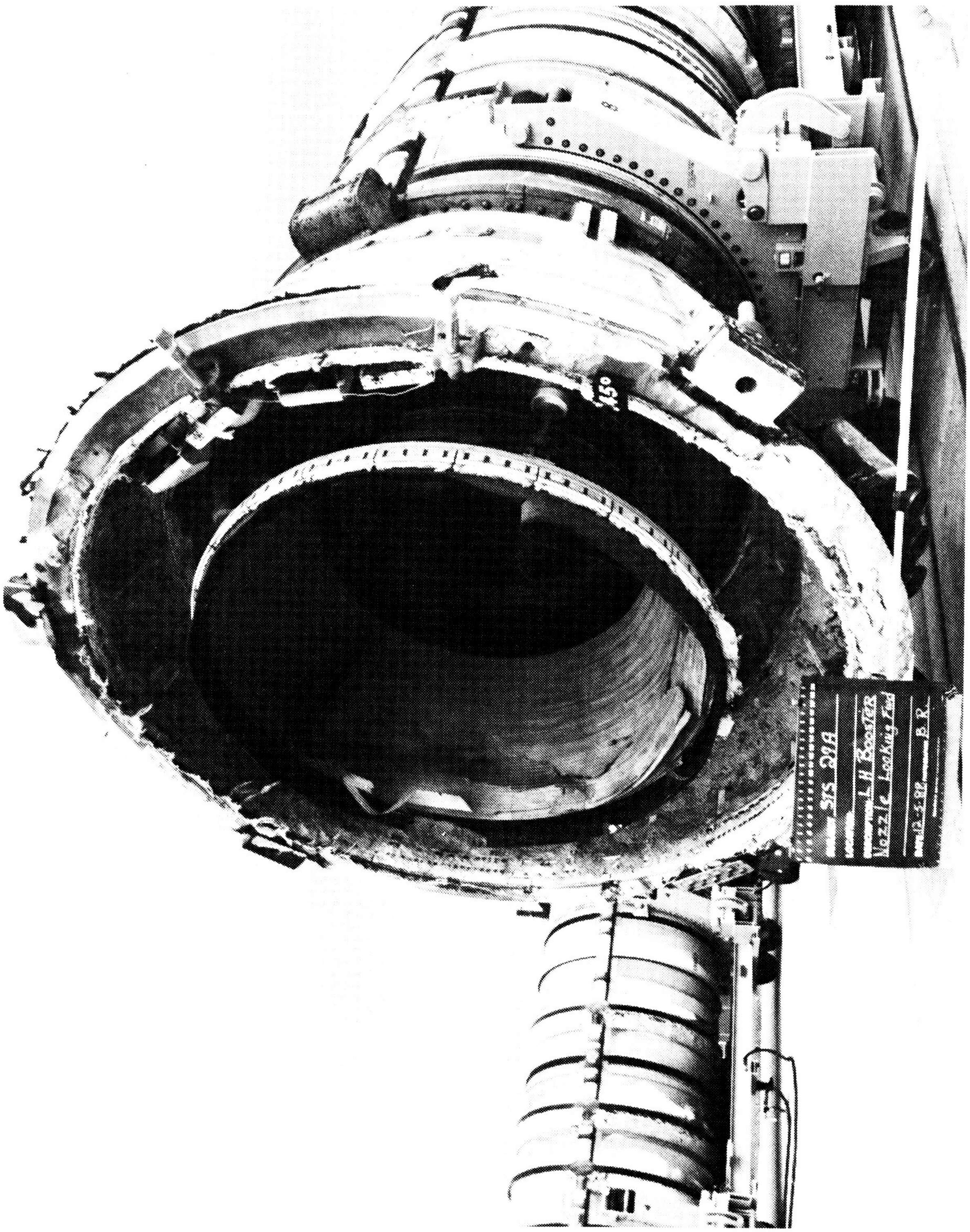

Figure 4.7 STS-27A Aft Exit Cone

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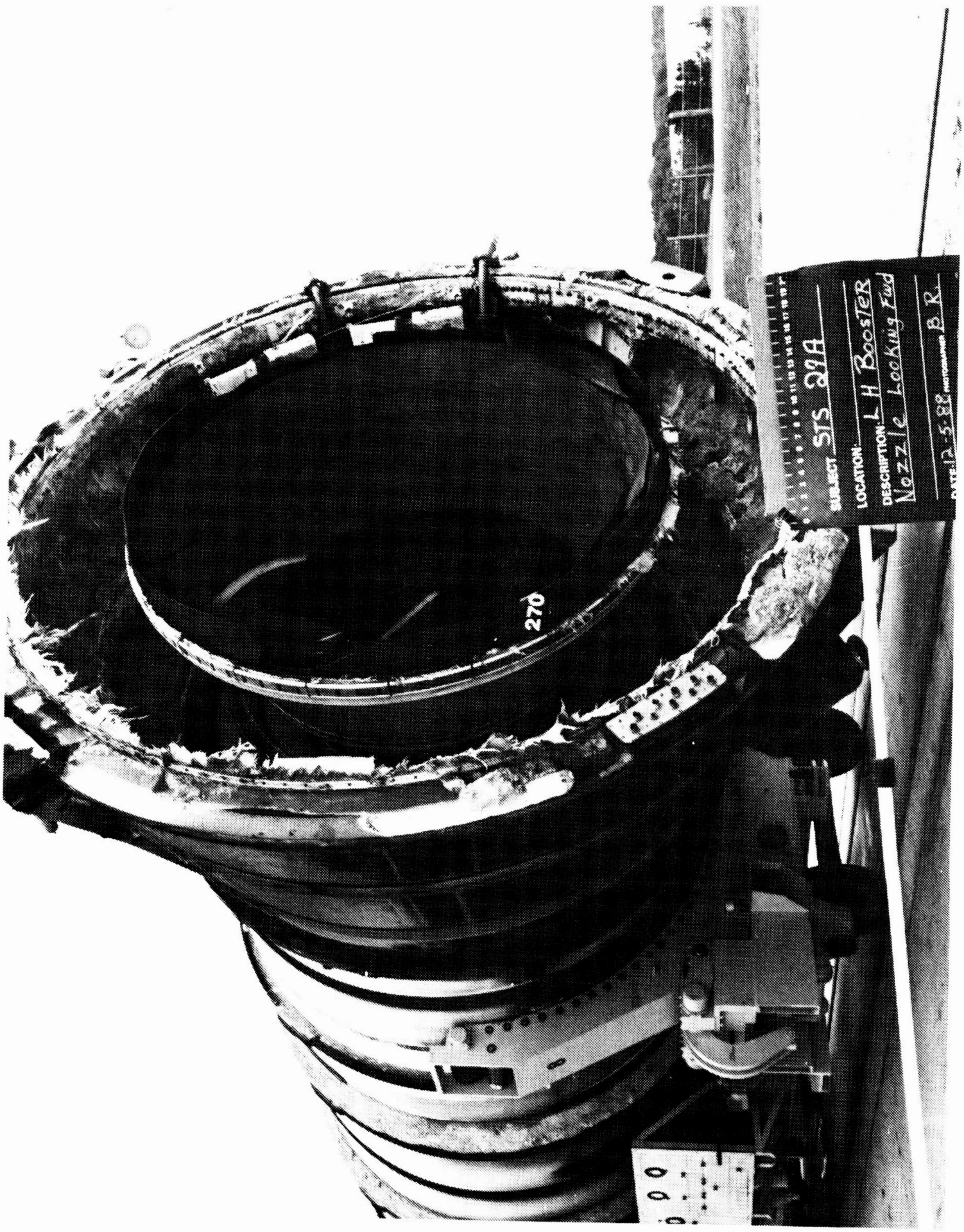
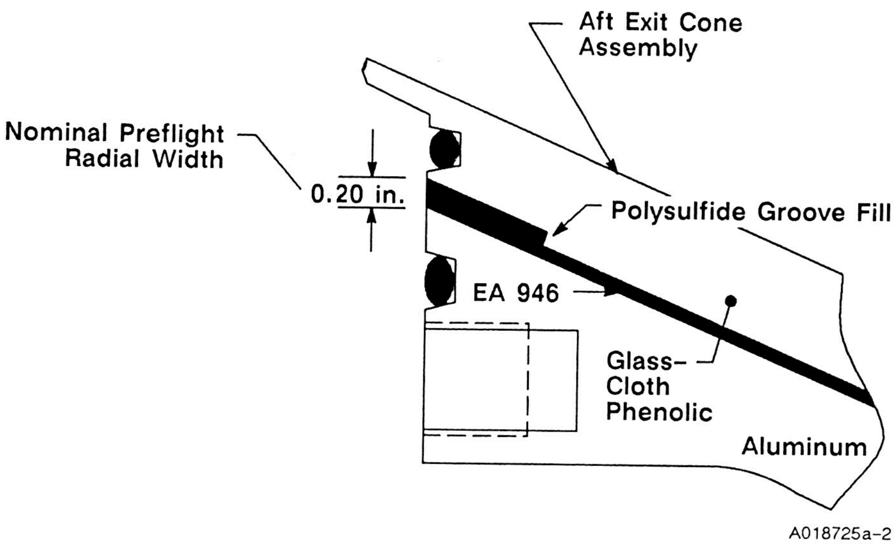


Figure 4.8 STS-27A Aft Exit Cone



Angular Location (deg)	Radial Width (in.)
0	0.18
30	0.17
60	0.18
90	0.18
120	0.18
150	0.18
180	0.17
210	0.18
240	0.18
270	0.17
300	0.18
330	0.18

Figure 4.9 STS-27A Polysulfide Groove Fill Post-Flight Radial Width Measurements

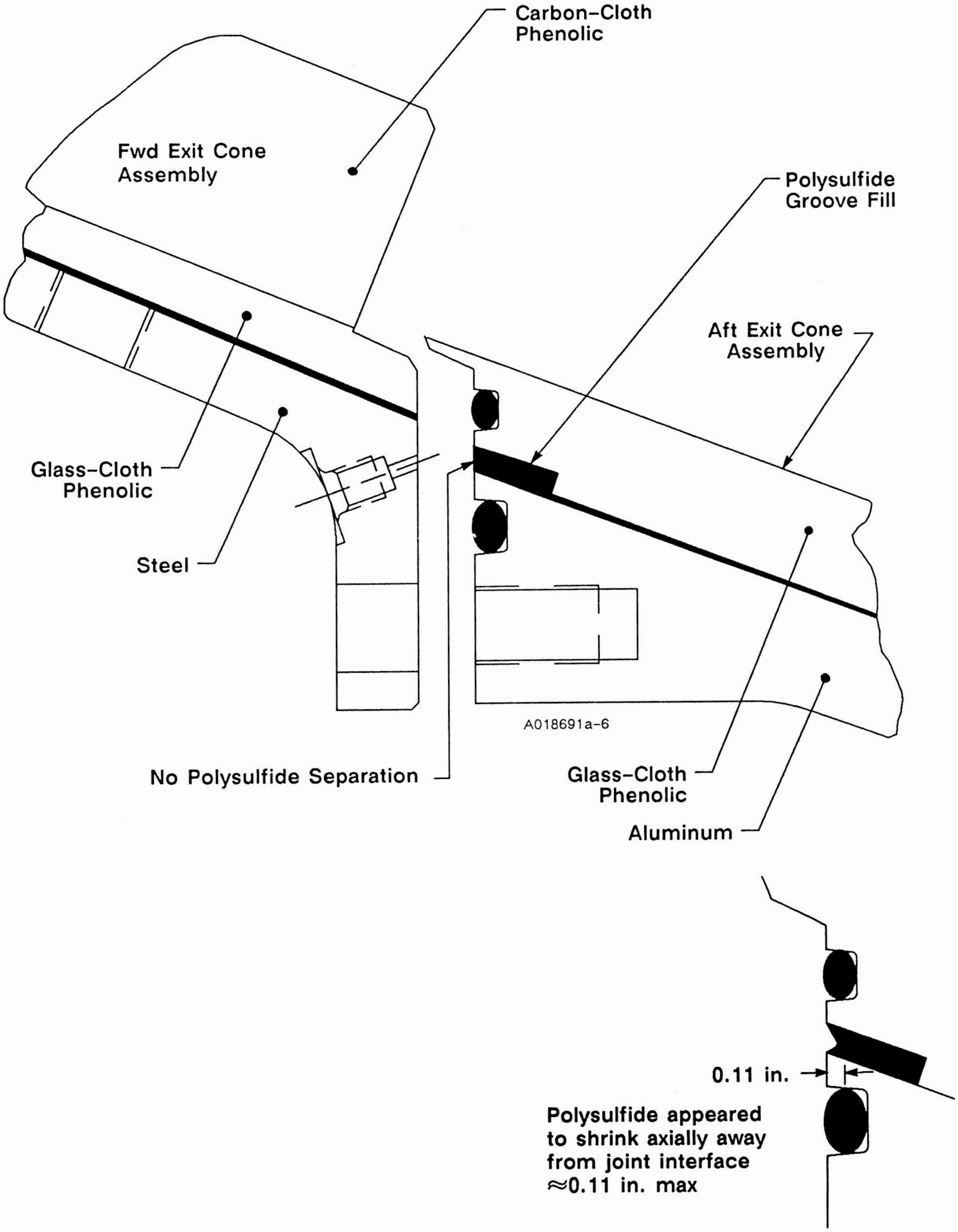
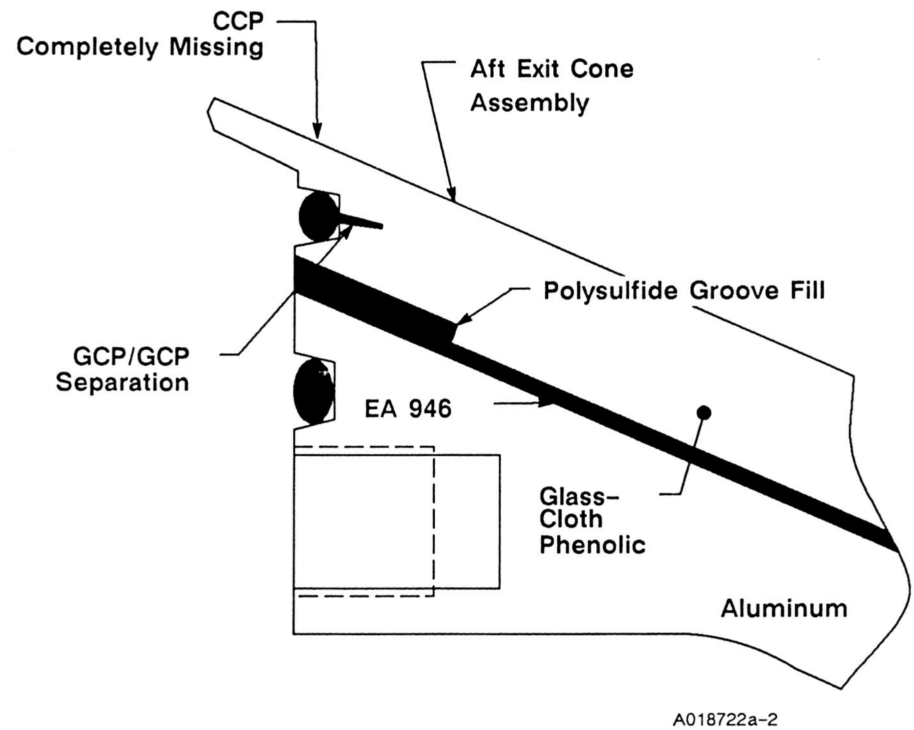


Figure 4.10 STS-27A Polysulfide Condition



GCP/CCP Separations

Location (deg)	Radial Width (in.)
0	0.01
15	0.005
30	0.005
45	0.003
60	0.005
75	0.015
90	0.03
105	0.04
345	0.05

Figure 4.11 STS-27A Aft Exit Cone Forwad End Phenolic Separations

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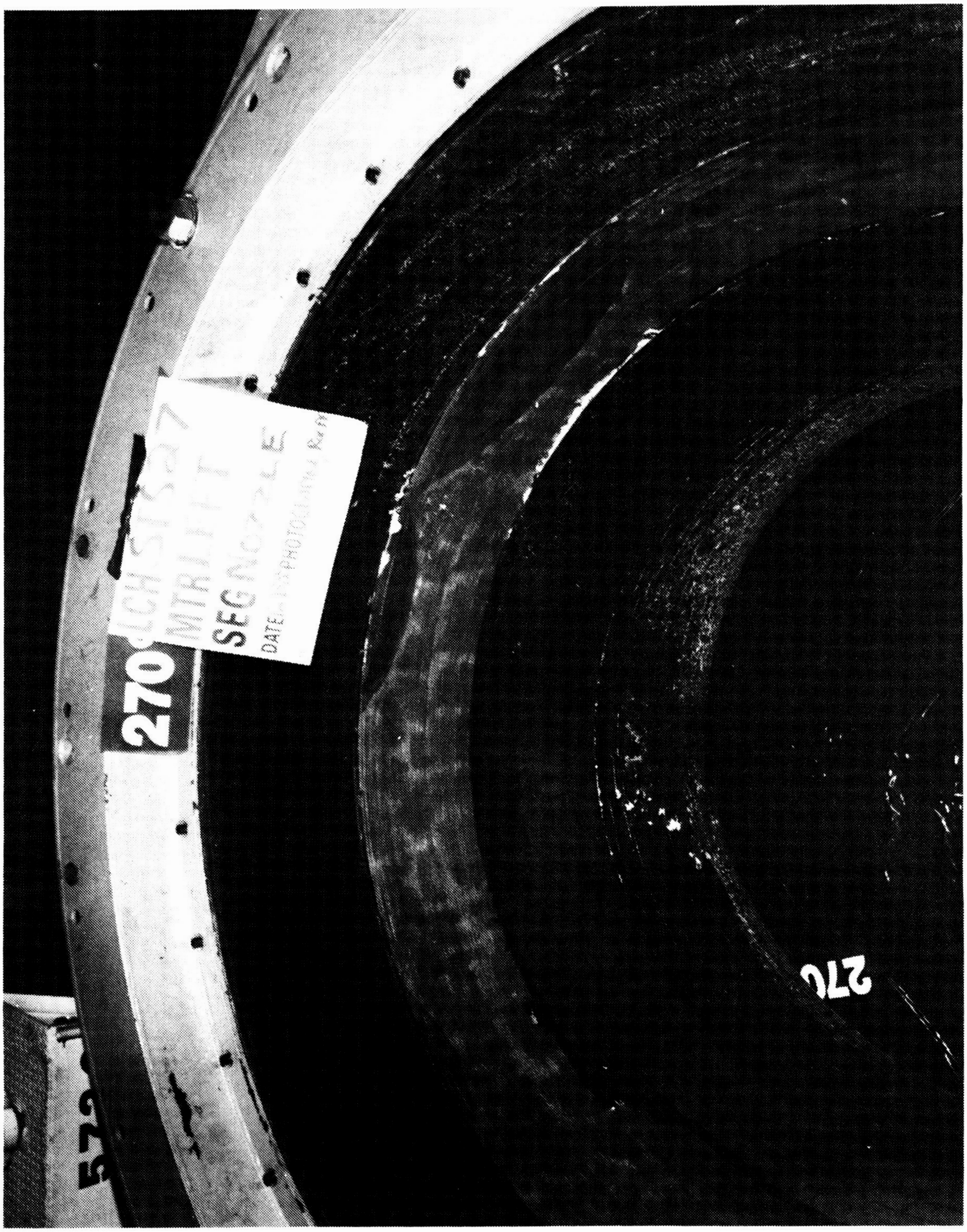

Figure 4.12 STS-27A Forward Exit Cone Overall View (270 degrees)

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Figure 4.13 STS-27A Forward Exit Cone Dimpled Erosion Pattern

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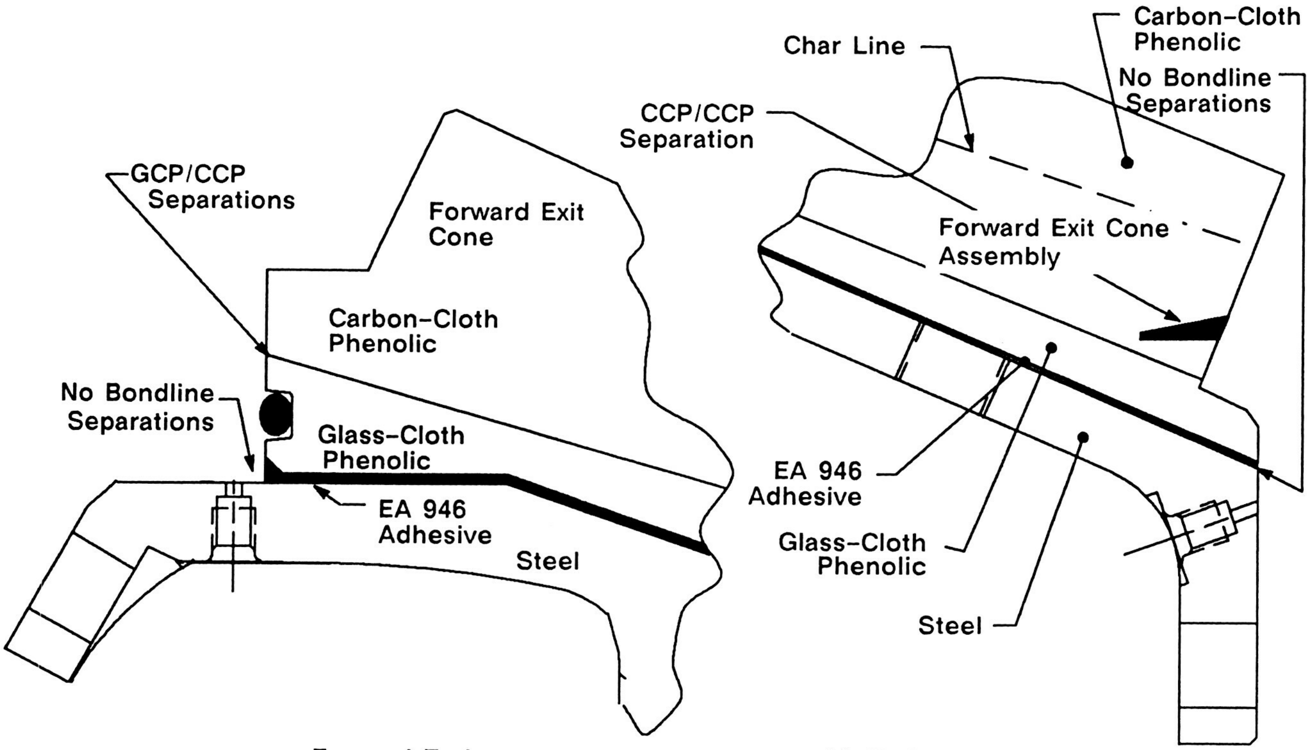

Forward End GCP/CCP Separations

Location (deg)	Radial Separation (in.)
0	0.06
15	0.06
30	0.06
45	--
60	0.01
75	0.01
90	0.01
105	--
120	--
135	--
150	--
165	0.01
180	0.01
195	0.01
210	--
225	0.005
240	0.005
255	0.005
270	0.01
285	0.01
300	--
315	0.01
330	0.02
345	0.04

Aft End CCP/CCP Separations

Location (deg)	Radial Separation (in.)
45	0.008
120	0.005

Figure 4.14 STS-27A Forward Exit Cone Separations

Table 4.1
STS-27A Forward Exit Cone Erosion and Char Data

Angular Location	Stations 1	4	8	12	16	20	24	28	32	34
0 degrees										
Measured Erosion	0.45	0.34	NA	NA	NA	NA	NA	0.28	0.21	0.21
Measured Char	0.70	0.70	NA	NA	NA	NA	NA	0.67	0.74	0.71
Adjusted Char*	0.56	0.56	NA	NA	NA	NA	NA	0.54	0.59	0.57
2E + 1.25AC	1.60	1.38	NA	NA	NA	NA	NA	1.23	1.16	1.13
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	0.13	0.26	NA	NA	NA	NA	NA	0.08	0.18	0.24
90 degrees										
Measured Erosion	0.55	0.36	0.37	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.59	0.66	0.69	NA	NA	NA	NA	NA	NA	NA
Adjusted Char*	0.47	0.53	0.55	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.69	1.38	1.43	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	0.07	0.26	0.14	NA	NA	NA	NA	NA	NA	NA
180 degrees										
Measured Erosion	0.41	0.38	0.35	0.26	NA	NA	NA	NA	NA	NA
Measured Char	0.71	0.70	0.69	0.74	NA	NA	NA	NA	NA	NA
Adjusted Char*	0.57	0.56	0.55	0.59	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.53	1.46	1.39	1.26	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	0.18	0.19	0.17	0.21	NA	NA	NA	NA	NA	NA
270 degrees										
Measured Erosion	0.56	0.37	0.41	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.54	0.69	0.65	NA	NA	NA	NA	NA	NA	NA
Adjusted Char*	0.43	0.55	0.52	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.66	1.43	1.47	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	0.09	0.21	0.11	NA	NA	NA	NA	NA	NA	NA
135 degrees										
Measured Erosion	0.56	0.38	0.39	0.31	NA	NA	NA	NA	NA	NA
Measured Char	0.56	0.68	0.68	0.69	NA	NA	NA	NA	NA	NA
Adjusted Char*	0.45	0.54	0.54	0.55	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.68	1.44	1.46	1.31	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	0.08	0.20	0.12	0.16	NA	NA	NA	NA	NA	NA

* Measured Char Adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

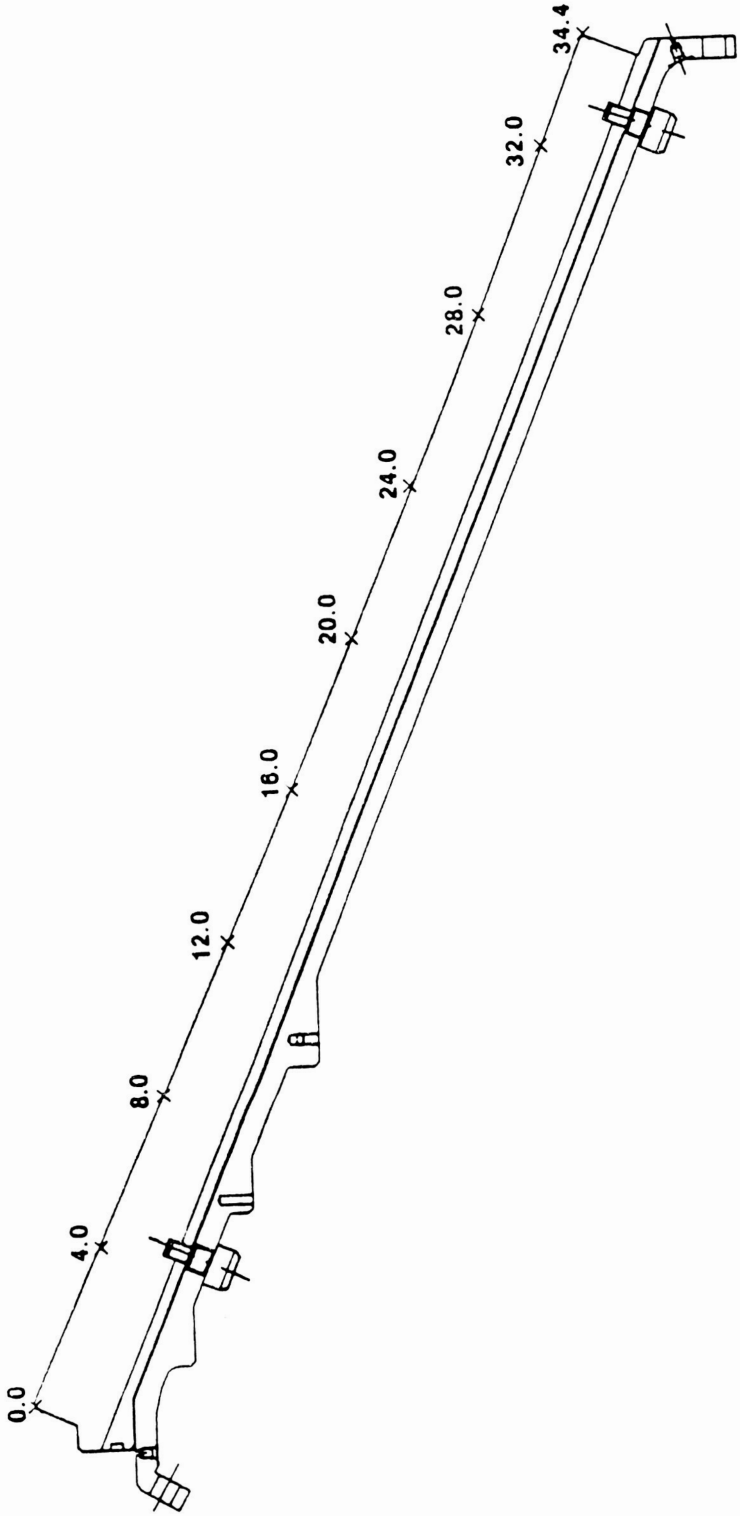

Figure 4.15 Forward Exit Cone Assembly Nozzle Stations

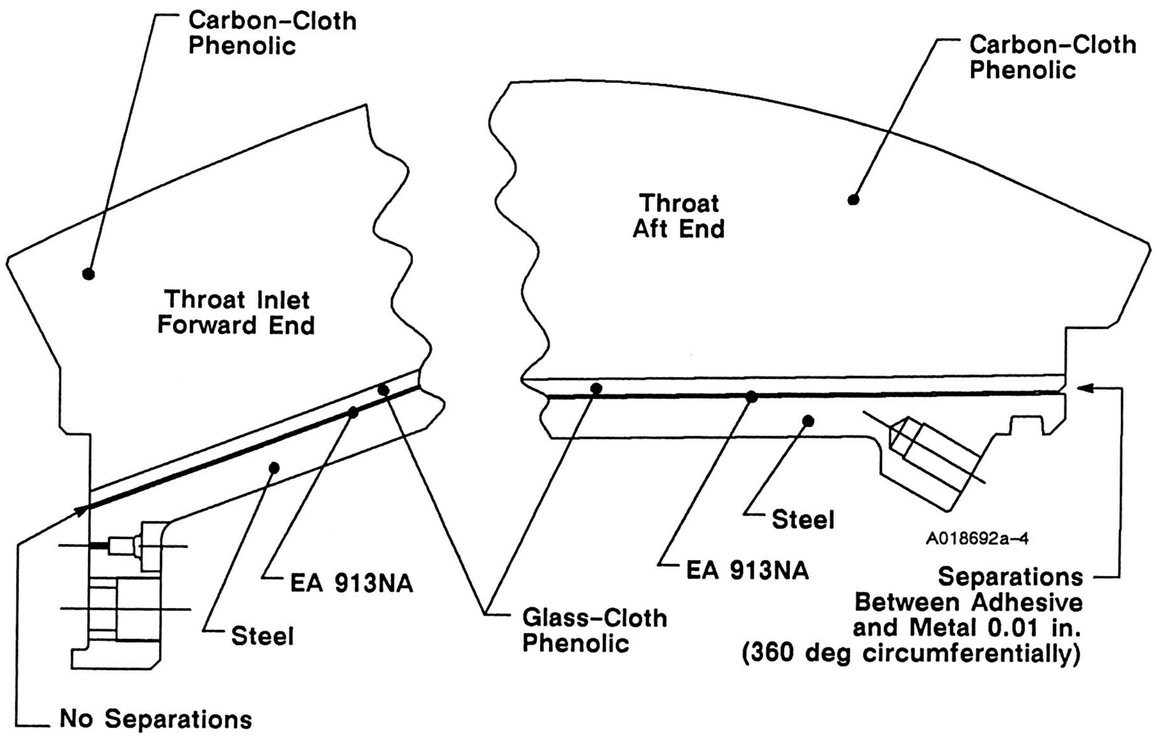

Figure 4.16 STS-27A Throat Assembly Separations

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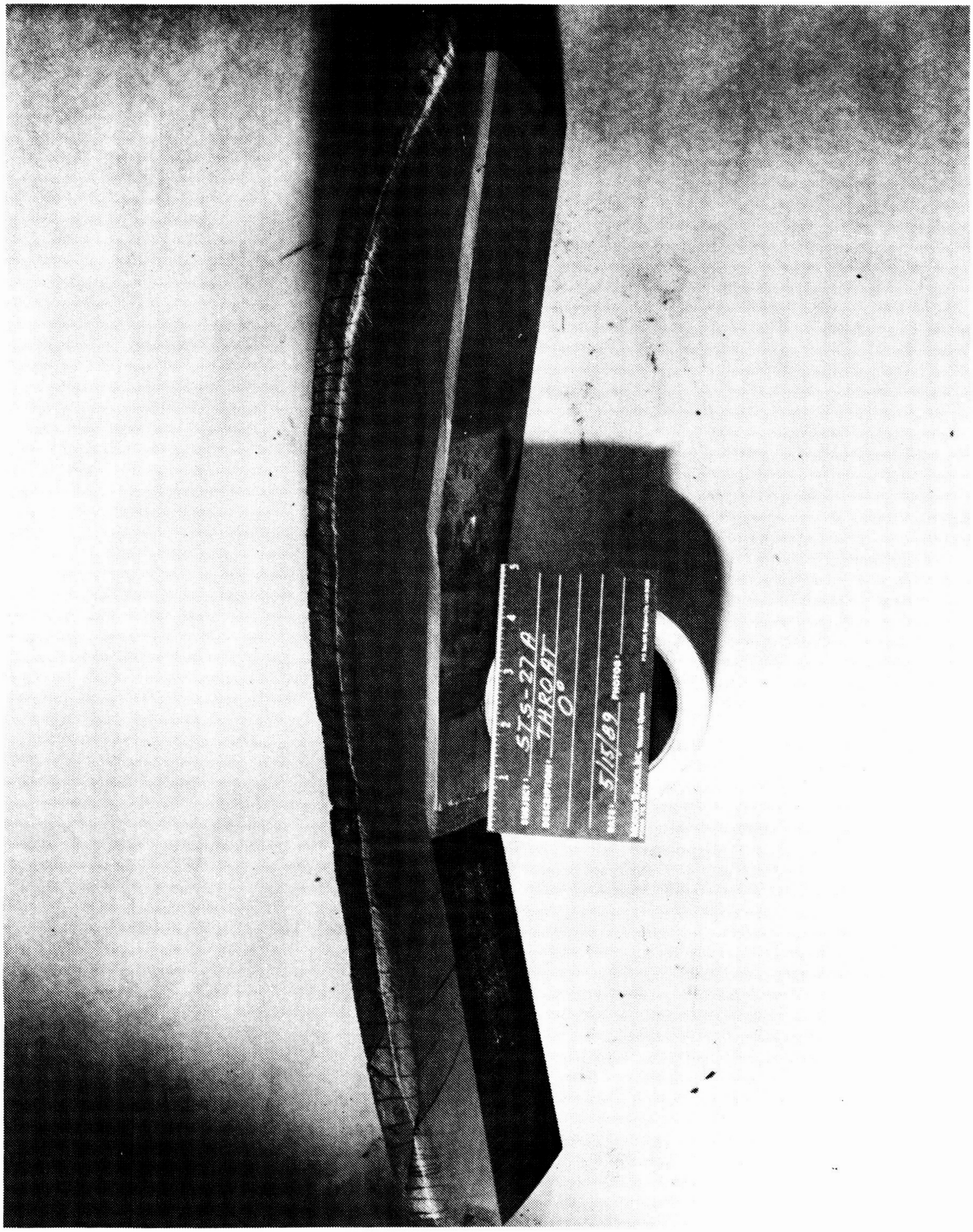

Figure 4.17 STS-27A Throat and Throat Inlet Rings Sectioned View (0 degrees)

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Figure 4.18 STS-27A Throat and Throat Inlet Rings Sectioned View (180 degrees)

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Table 4.2

STS-27A Throat Assembly Erosion and Char Data

Angular Location	Stations												
0 degrees	1	2	4	6	8	10	12	14	16	18	20	22	23
Measured Erosion	1.11	1.11	1.19	1.21	1.25	1.17	1.16	1.12	1.09	0.90	0.65	0.45	0.40
Measured Char	0.67	0.67	0.60	0.67	0.59	0.63	0.57	0.58	0.60	0.65	0.74	0.77	0.85
Adjusted Char *	0.50	0.50	0.45	0.50	0.44	0.47	0.43	0.44	0.45	0.49	0.56	0.58	0.64
2E + 1.25AC	2.85	2.85	2.94	3.05	3.05	2.93	2.85	2.78	2.74	2.41	1.99	1.62	1.60
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.11	0.14	0.13	0.08	0.04	0.16	0.23	0.30	0.35	0.49	0.62	0.59	0.32
90 degrees													
Measured Erosion	1.05	1.06	1.15	1.13	1.16	1.13	1.08	1.07	1.05	0.90	0.69	0.47	0.38
Measured Char	0.61	0.67	0.63	0.63	0.62	0.56	0.56	0.57	0.57	0.64	0.68	0.85	0.87
Adjusted Char *	0.46	0.50	0.47	0.47	0.47	0.42	0.42	0.43	0.43	0.48	0.51	0.64	0.65
2E + 1.25AC	2.67	2.75	2.89	2.85	2.90	2.79	2.69	2.67	2.63	2.40	2.02	1.74	1.58
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.19	0.18	0.15	0.15	0.10	0.22	0.31	0.36	0.41	0.49	0.60	0.49	0.34
180 degrees													
Measured Erosion	1.02	1.05	1.10	1.15	1.17	1.13	1.10	1.07	1.04	0.85	0.65	0.46	0.40
Measured Char	0.60	0.60	0.63	0.62	0.58	0.58	0.57	0.57	0.54	0.68	0.75	0.82	0.92
Adjusted Char *	0.45	0.45	0.47	0.47	0.44	0.44	0.43	0.43	0.41	0.51	0.56	0.62	0.69
2E + 1.25AC	2.60	2.66	2.79	2.88	2.88	2.80	2.73	2.67	2.59	2.34	2.00	1.69	1.66
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.22	0.22	0.19	0.14	0.11	0.21	0.29	0.36	0.43	0.53	0.61	0.53	0.27
270 degrees													
Measured Erosion	1.02	1.08	1.13	1.16	1.19	1.15	1.11	1.09	1.04	0.90	0.65	0.47	0.40
Measured Char	0.70	0.69	0.67	0.61	0.55	0.62	0.58	0.57	0.57	0.63	0.75	0.76	0.85
Adjusted Char *	0.53	0.52	0.50	0.46	0.41	0.47	0.44	0.43	0.43	0.47	0.56	0.57	0.64
2E + 1.25AC	2.70	2.81	2.89	2.89	2.90	2.88	2.76	2.71	2.61	2.39	2.00	1.65	1.60
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.18	0.16	0.15	0.13	0.10	0.18	0.27	0.34	0.42	0.50	0.61	0.56	0.32

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

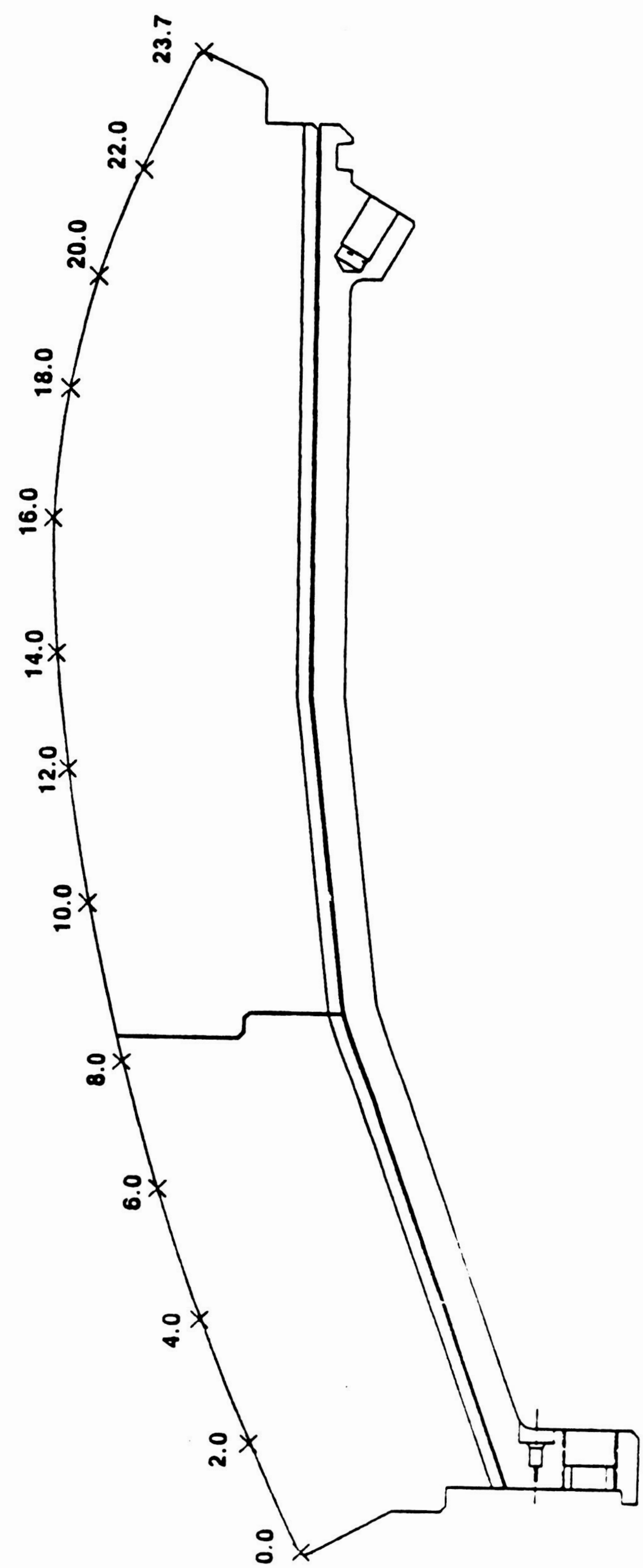

Figure 4.19 Throat Inlet Assembly Erosion Measurement Stations

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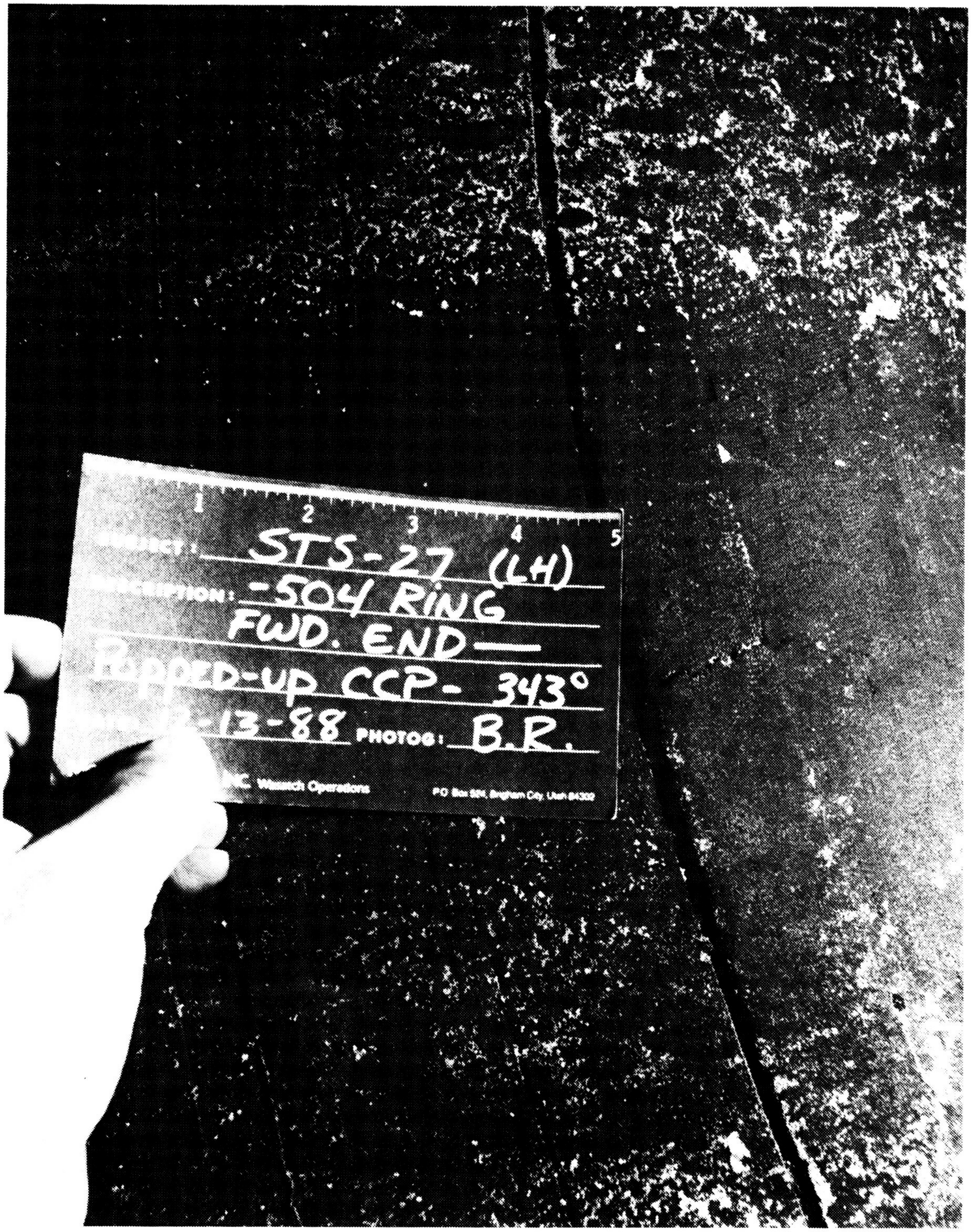

Figure 4.20 STS-27A -504 Ring Forward End Popped-Up Charred CCP (343 degrees)

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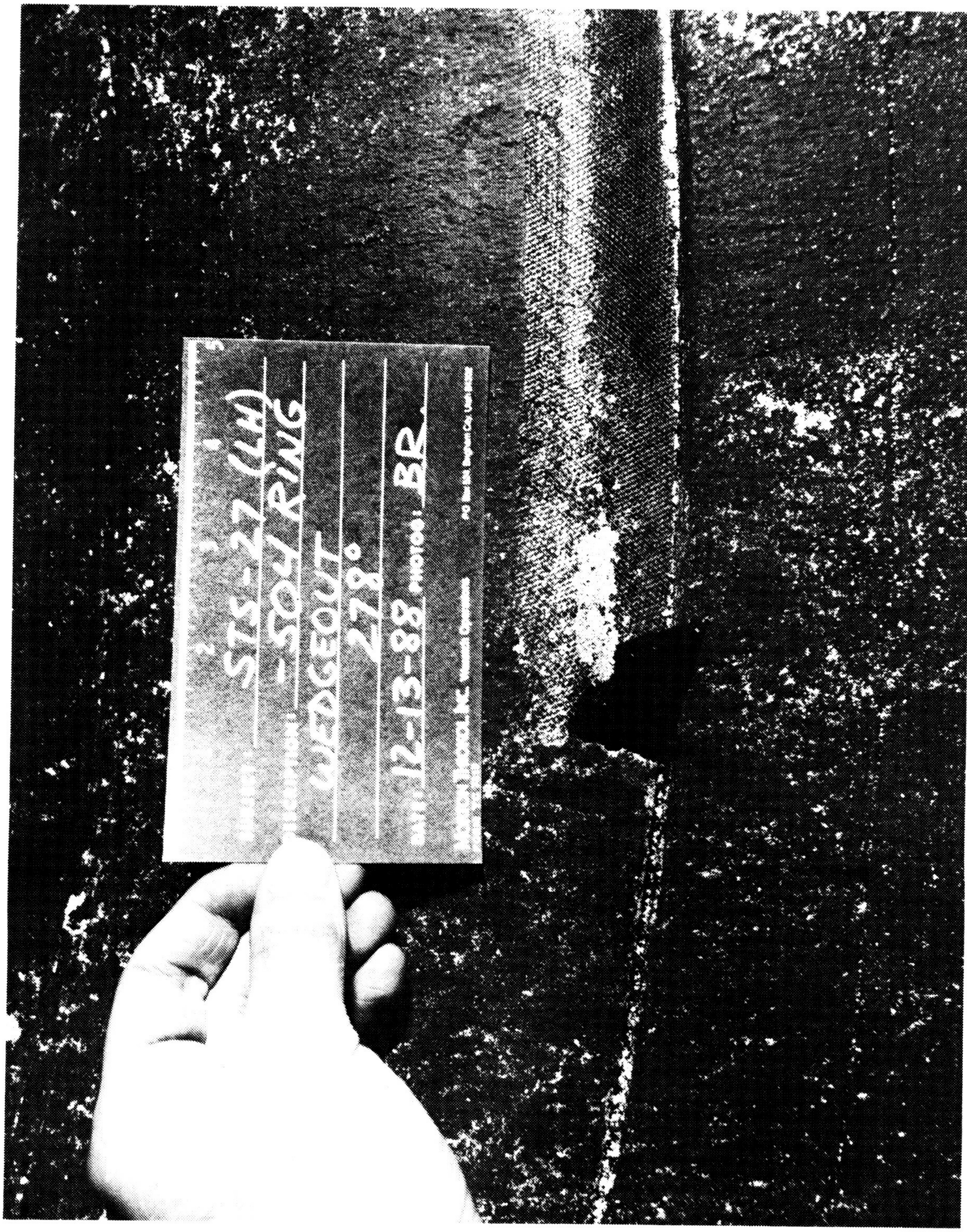

Figure 4.21 STS-27A -504 Ring Forward End Wedged Out Charred CCP
(278 degrees)

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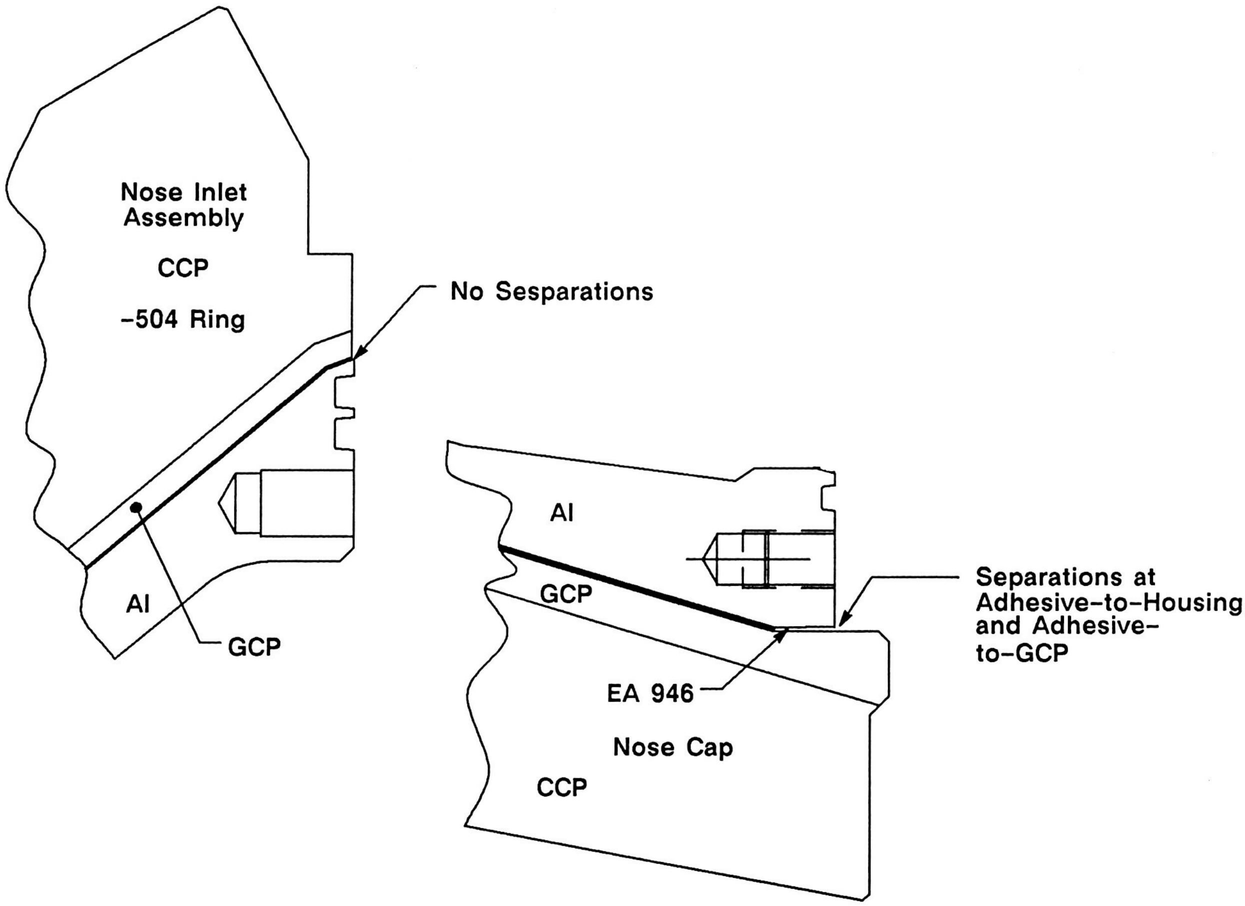
Figure 4.22 STS-27A Nose Cap Aft End Wedgeout (260 degrees)



Location (deg)	Nose Cap Aft End Radial Bondline Separation (in.)	Separation Type*
30	0.002	1
90	0.005	2
105	0.005	2
195	0.002	2
315	0.005	2
330	0.005	2
345	0.005	2

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* Type 2 = Adhesive-to-GCP
Type 1 = Metal-to-Adhesive

Figure 4.23 STS-27A Nose Inlet Assembly Separations

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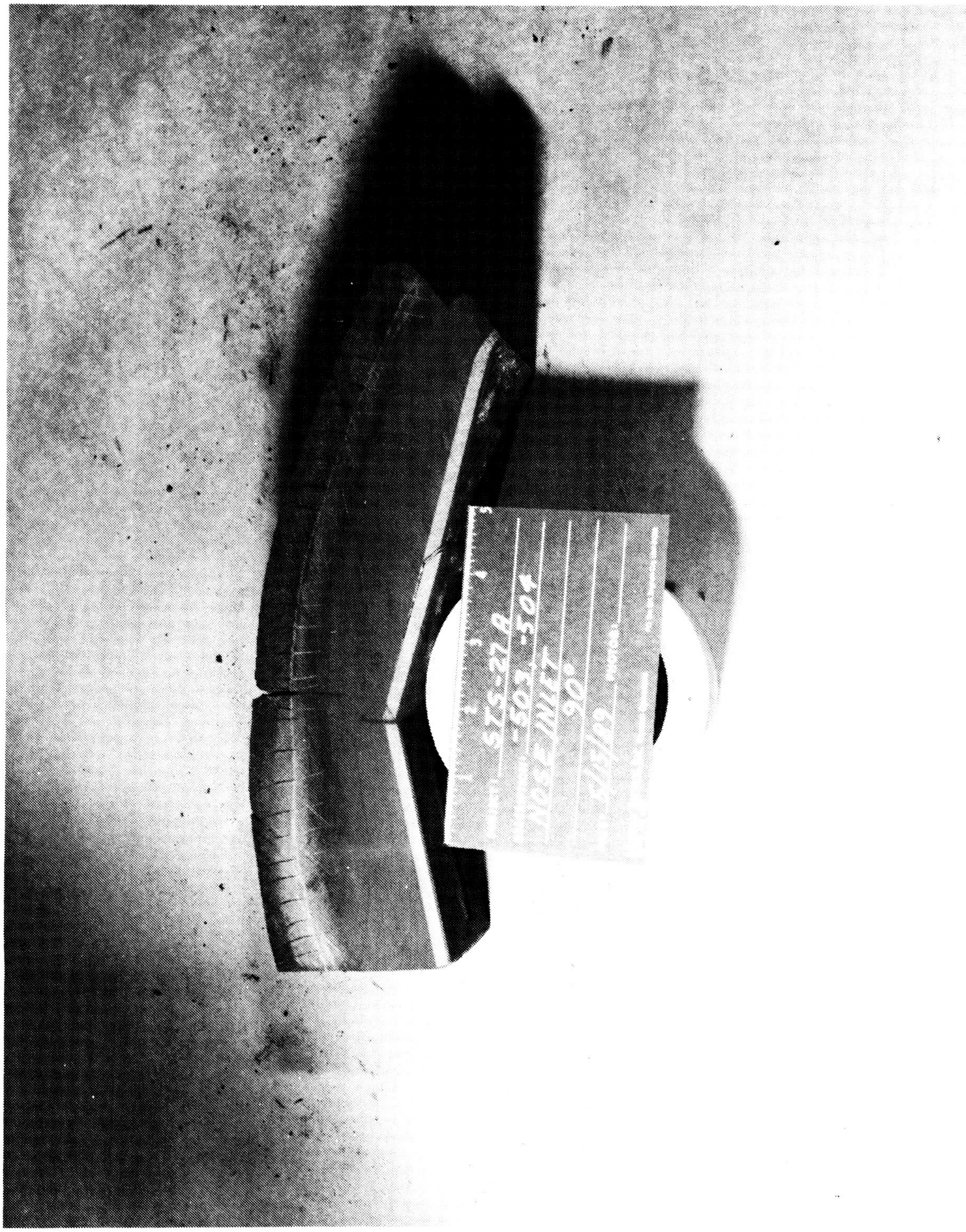

Figure 4.24 STS-27A -503/-504 Ring Sectioned View (90 degrees)

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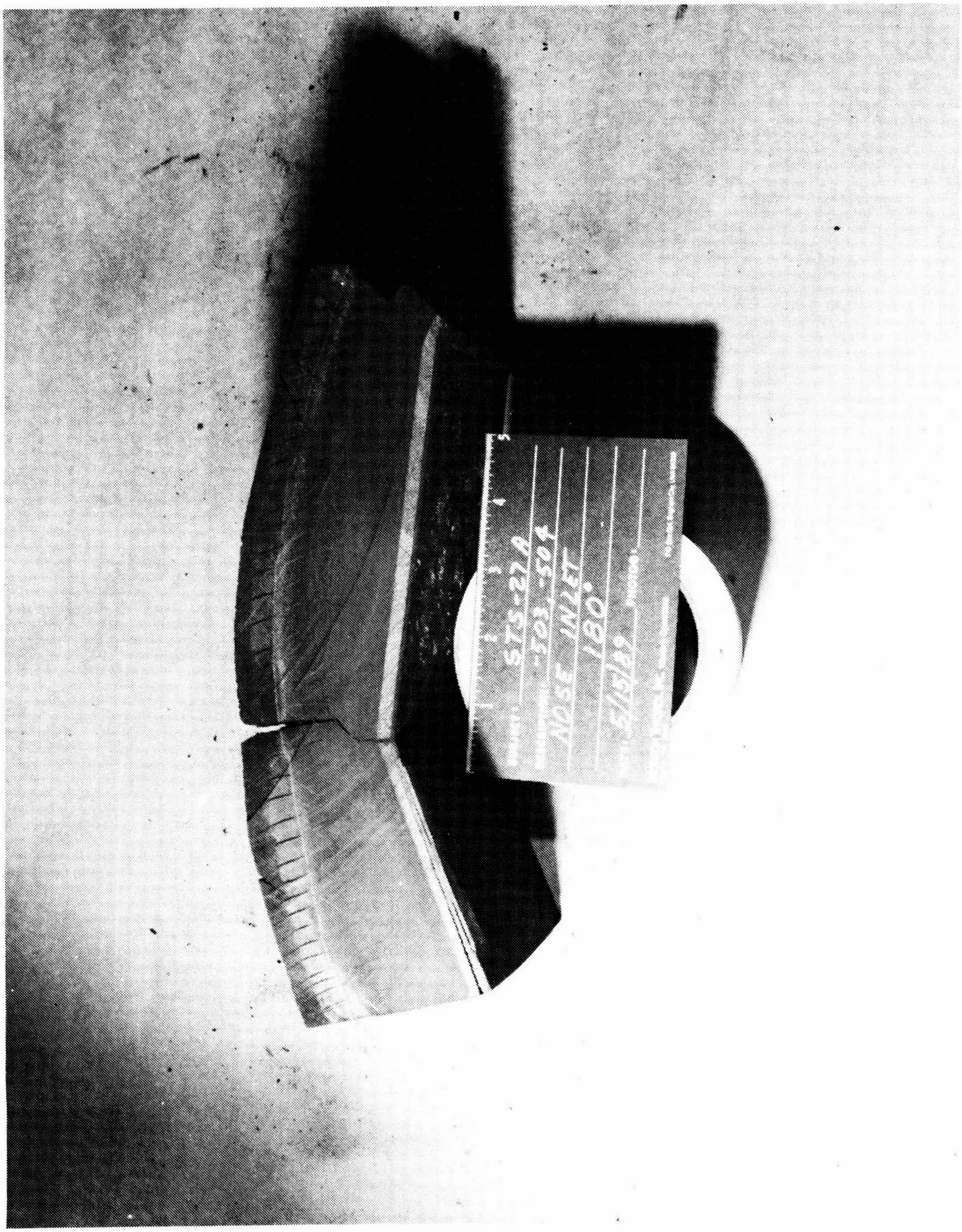

Figure 4.25 STS-27A -503/-504 Ring Sectioned View (180 degrees)

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Figure 4.26 STS-27A Nose Cap Sectioned View (90 degrees)

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Table 4.3

STS-27A Nose Inlet Rings (-503, -504) Erosion and Char Data

Angular Location	Stations						
	28	30	32	34	36	38	39
0 degrees							
Measured Erosion	1.20	0.98	0.90	0.88	0.90	0.97	0.99
Measured Char	0.73	0.65	0.65	0.57	0.60	0.65	0.67
Adjusted Char*	0.55	0.49	0.49	0.43	0.45	0.49	0.50
2E + 1.25AC	3.08	2.57	2.41	2.29	2.36	2.55	2.61
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.14	0.27	0.22	0.39	0.35	0.19	0.15
90 degrees							
Measured Erosion	1.09	0.86	0.89	0.84	0.90	0.97	0.94
Measured Char	0.76	0.66	0.60	0.60	0.58	0.60	0.65
Adjusted Char*	0.57	0.50	0.45	0.45	0.44	0.45	0.49
2E + 1.25AC	2.89	2.34	2.34	2.24	2.34	2.50	2.49
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.21	0.39	0.26	0.42	0.37	0.21	0.21
180 degrees							
Measured Erosion	1.05	0.82	0.85	0.83	0.87	0.94	0.92
Measured Char	0.70	0.80	0.68	0.61	0.57	0.55	0.60
Adjusted Char*	0.53	0.60	0.51	0.46	0.43	0.41	0.45
2E + 1.25AC	2.76	2.39	2.34	2.23	2.27	2.40	2.40
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.27	0.36	0.26	0.43	0.41	0.26	0.25
270 degrees							
Measured Erosion	1.13	0.91	0.87	0.89	0.92	0.97	0.98
Measured Char	0.64	0.68	0.63	0.59	0.61	0.60	0.60
Adjusted Char*	0.48	0.51	0.47	0.44	0.46	0.45	0.45
2E + 1.25AC	2.86	2.46	2.33	2.33	2.41	2.50	2.52
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.23	0.32	0.27	0.36	0.33	0.21	0.19
15 degrees							
Measured Erosion	1.20	0.98	0.90	0.90	0.91	0.98	0.97
Measured Char	0.72	0.70	0.65	0.59	0.64	0.57	0.67
Adjusted Char*	0.54	0.53	0.49	0.44	0.48	0.43	0.50
2E + 1.25AC	3.08	2.62	2.41	2.35	2.42	2.49	2.57
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.14	0.24	0.22	0.35	0.32	0.21	0.17

* Measured Char Adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

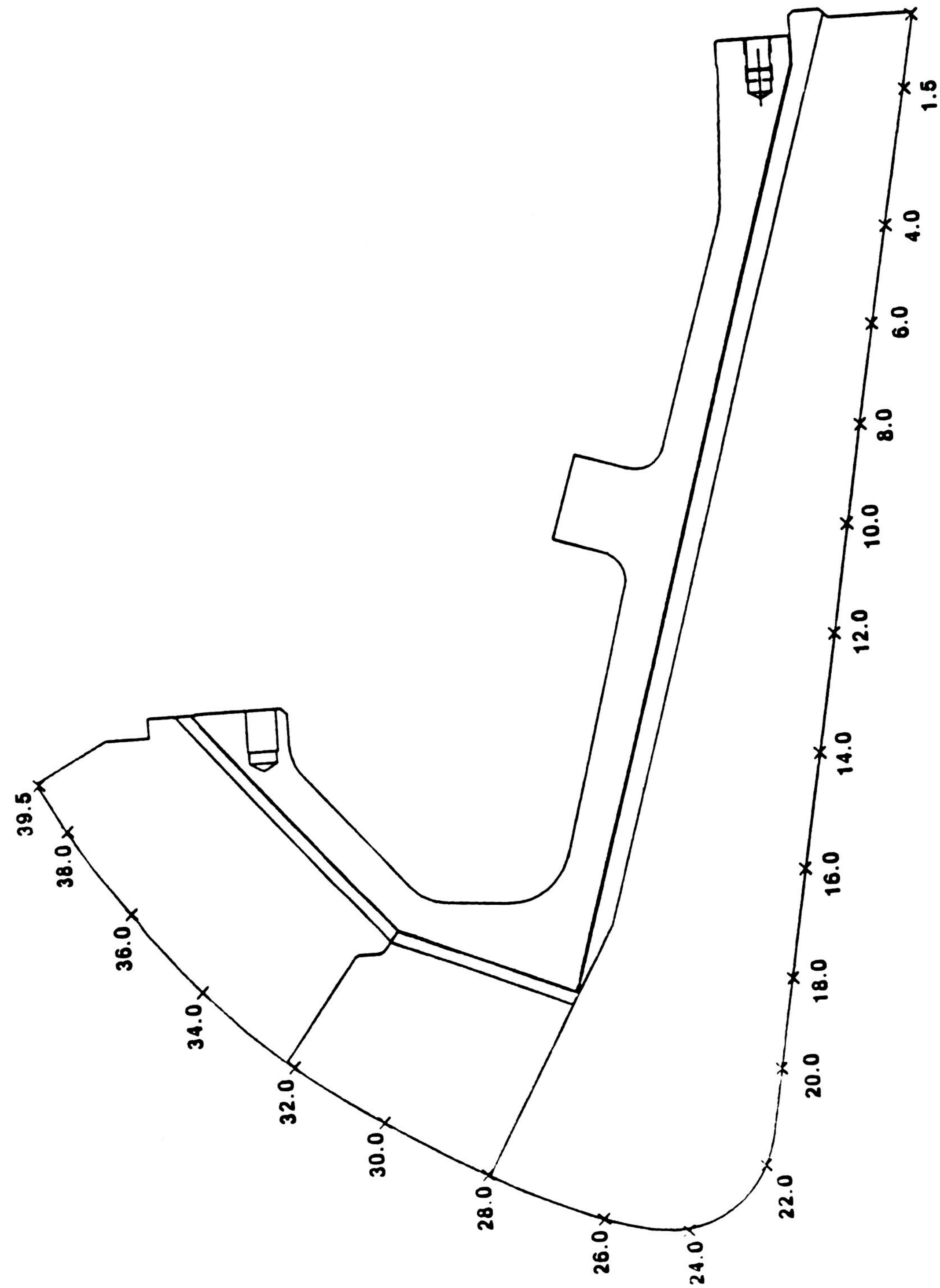

Figure 4.27 Nose Inlet Assembly Erosion Measurement Stations

Table 4.4

STS-27A Nose Cap Assembly Erosion and Char Data

Angular Location	Stations												
	1.5	4	6	8	10	12	14	16	18	20	22	24	26
0 degrees													
Measured Erosion	NA	0.42	0.43	0.50	0.55	0.58	0.69	0.68	0.89	1.17	1.75	1.97	1.41
Measured Char	NA	0.64	0.59	0.58	0.65	0.59	0.57	0.56	0.50	0.61	0.67	0.77	0.80
Adjusted Char *	NA	0.51	0.47	0.46	0.52	0.47	0.46	0.45	0.40	0.49	0.54	0.62	0.60
2E + 1.25AC	NA	1.48	1.45	1.58	1.75	1.75	1.95	1.92	2.28	2.95	4.17	4.71	3.57
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.38	0.55	0.56	0.52	0.64	0.58	0.72	0.54	0.37	0.13	0.00	0.08
45 degrees													
Measured Erosion	NA	0.34	0.35	0.40	0.51	0.58	0.60	0.64	0.80	1.05	1.53	1.67	1.15
Measured Char	NA	0.63	0.64	0.61	0.49	0.42	0.54	0.56	0.55	0.59	0.71	0.63	0.79
Adjusted Char *	NA	0.50	0.51	0.49	0.39	0.34	0.43	0.45	0.44	0.47	0.57	0.50	0.59
2E + 1.25AC	NA	1.31	1.34	1.41	1.51	1.58	1.74	1.84	2.15	2.69	3.77	3.97	3.04
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.56	0.68	0.74	0.77	0.82	0.77	0.79	0.63	0.51	0.25	0.18	0.27
90 degrees													
Measured Erosion	NA	0.37	0.39	0.40	0.43	0.48	0.57	0.61	0.77	1.03	1.45	1.82	1.15
Measured Char	NA	0.67	0.61	0.57	0.54	0.50	0.50	0.58	0.58	0.48	0.71	0.75	0.73
Adjusted Char *	NA	0.54	0.49	0.46	0.43	0.40	0.40	0.46	0.46	0.38	0.57	0.60	0.55
2E + 1.25AC	NA	1.41	1.39	1.37	1.40	1.46	1.64	1.80	2.12	2.54	3.61	4.39	2.98
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.45	0.62	0.79	0.91	0.97	0.88	0.83	0.65	0.60	0.31	0.07	0.29
135 degrees													
Measured Erosion	NA	0.35	0.36	0.40	0.39	0.50	0.57	0.62	0.54	0.96	1.49	1.69	1.23
Measured Char	NA	0.69	0.67	0.63	0.62	0.57	0.49	0.49	0.46	0.53	0.67	0.81	0.82
Adjusted Char *	NA	0.55	0.54	0.50	0.50	0.46	0.39	0.39	0.37	0.42	0.54	0.65	0.62
2E + 1.25AC	NA	1.39	1.39	1.43	1.40	1.57	1.63	1.73	1.54	2.45	3.65	4.19	3.23
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.47	0.62	0.72	0.91	0.83	0.89	0.91	1.28	0.66	0.29	0.12	0.20

* measured char adjusted to end of action time

$$\text{margin of safety} = \frac{\text{minimum liner thickness}}{\text{2 X erosion + 1.25 X adj char*}} - 1$$

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Table 4.4 (continued)

STS-27A Nose Cap Assembly Erosion and Char Data

Angular Location	Stations												
	1.5	4	6	8	10	12	14	16	18	20	22	24	26
180 degrees													
Measured Erosion	NA	0.32	0.36	0.38	0.37	0.46	0.56	0.59	0.72	0.91	1.29	1.55	NA
Measured Char	NA	0.62	0.56	0.63	0.56	0.53	0.53	0.56	0.54	0.50	0.79	0.67	NA
Adjusted Char *	NA	0.50	0.45	0.50	0.45	0.42	0.42	0.45	0.43	0.40	0.63	0.54	NA
2E + 1.25AC	NA	1.26	1.28	1.39	1.30	1.45	1.65	1.74	1.98	2.32	3.37	3.77	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.62	0.76	0.77	1.05	0.98	0.87	0.90	0.77	0.75	0.40	0.24	NA
225 degrees													
Measured Erosion	NA	0.37	0.38	0.40	0.40	0.49	0.54	0.58	0.72	0.95	1.47	1.72	1.27
Measured Char	NA	0.60	0.55	0.52	0.59	0.50	0.49	0.53	0.51	0.49	0.70	0.71	0.80
Adjusted Char *	NA	0.48	0.44	0.42	0.47	0.40	0.39	0.42	0.41	0.39	0.56	0.57	0.60
2E + 1.25AC	NA	1.34	1.31	1.32	1.39	1.48	1.57	1.69	1.95	2.39	3.64	4.15	3.29
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.52	0.72	0.86	0.92	0.94	0.97	0.95	0.80	0.70	0.29	0.13	0.17
270 degrees													
Measured Erosion	NA	0.36	0.39	0.39	0.45	0.54	0.66	0.71	0.81	1.12	1.63	1.81	1.29
Measured Char	NA	0.63	0.67	0.68	0.62	0.55	0.54	0.48	0.47	0.47	0.65	0.73	0.81
Adjusted Char *	NA	0.50	0.54	0.54	0.50	0.44	0.43	0.38	0.38	0.38	0.52	0.58	0.61
2E + 1.25AC	NA	1.35	1.45	1.46	1.52	1.63	1.86	1.90	2.09	2.71	3.91	4.35	3.34
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.51	0.55	0.68	0.76	0.77	0.66	0.74	0.68	0.50	0.21	0.08	0.16
315 degrees													
Measured Erosion	NA	0.38	0.39	0.43	0.51	0.58	0.67	0.72	0.87	1.11	1.71	1.90	1.39
Measured Char	NA	0.63	0.61	0.59	0.55	0.51	0.44	0.49	0.45	0.48	0.61	0.68	0.72
Adjusted Char *	NA	0.50	0.49	0.47	0.44	0.41	0.35	0.39	0.36	0.38	0.49	0.54	0.54
2E + 1.25AC	NA	1.39	1.39	1.45	1.57	1.67	1.78	1.93	2.19	2.70	4.03	4.48	3.46
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.47	0.62	0.70	0.70	0.72	0.73	0.71	0.60	0.50	0.17	0.05	0.12

* measured char adjusted to end of action time

$$\text{margin of safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

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Figure 4.28 STS-27A Nose Inlet Housing Aft End Damaged Helicoils (90 and 100 degrees)

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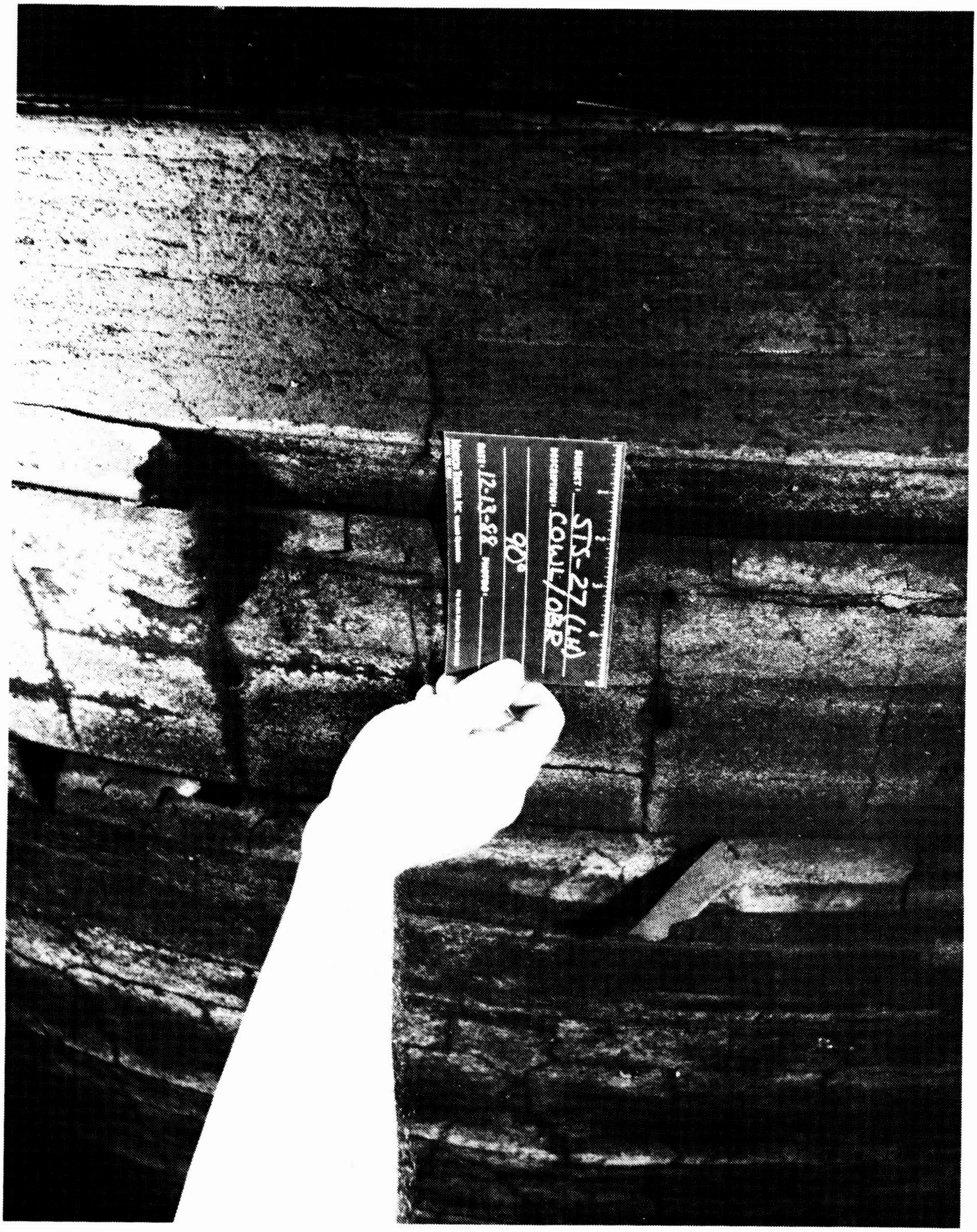

Figure 4.29 STS-27A Cowl/OBR (90 degrees)

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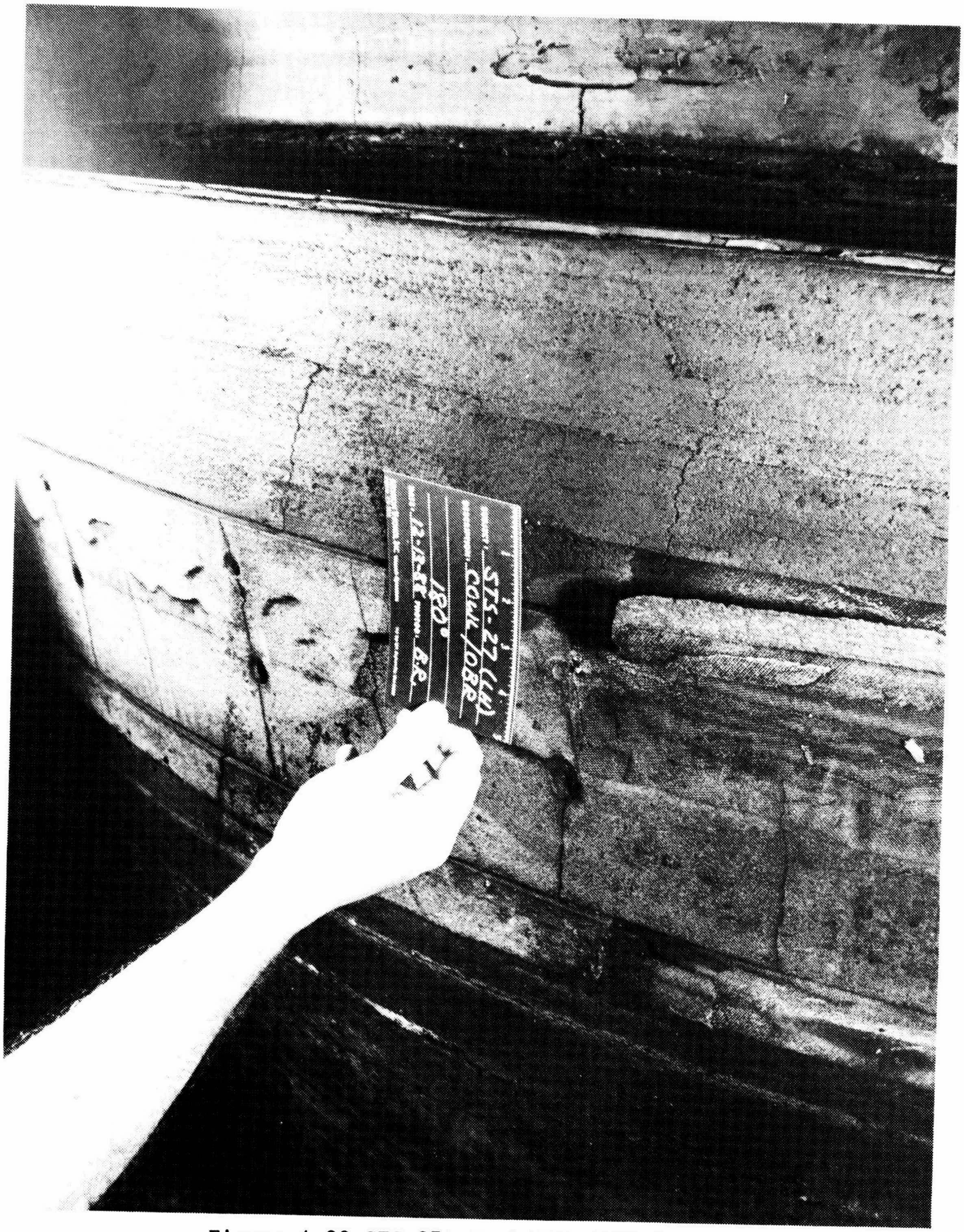

Figure 4.30 STS-27A Cowl/OBR (180 degrees)

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Figure 4.31 STS-27A Cowl/OBR (270 degrees)

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Figure 4.32 STS-27A Cowl Ring Aft End Post-Burn Wedgeout (290 degrees)

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Figure 4.33 STS-27A Cowl Ring Sectioned View (0 degrees)

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Figure 4.34 STS-27A Cowl Ring Sectioned View (180 degrees)

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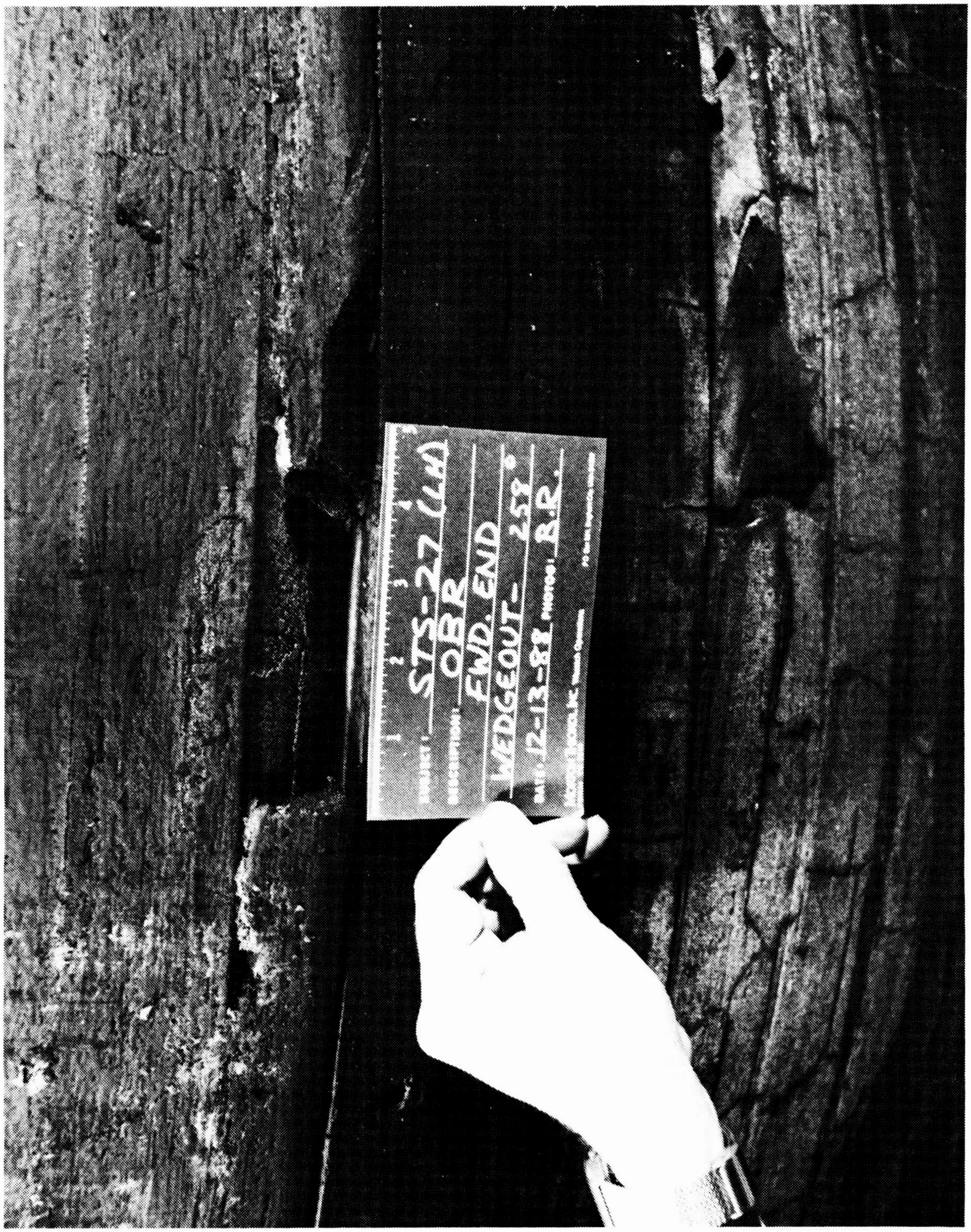

Figure 4.35 STS-27A OBR Forward End Post-Burn Wedgeout (258 degrees)

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Figure 4.36 STS-27A OBR/Flex Boot Sectioned View (0 degrees)

Figure 4.37 STS-27A OBR/Flex Boot Sectioned View (90 degrees)

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Figure 4.38 STS-27A OBR/Flex Boot Sectioned View (135 degrees)

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Figure 4.39 STS-27A OBR/Flex Boot Sectioned View (225 degrees)

Table 4.5

STS-27A Cowl/OBR Erosion and Char Data

Angular Location	Stations											
0 degrees	0	1	2	3	4	5	6	7	8	9	10	11.3
Measured Erosion	0.23	0.28	0.28	0.31	0.32	0.30	0.17	0.13	NA	NA	0.00	0.00
Measured Char	0.66	0.69	0.72	0.66	0.67	0.68	0.85	0.86	NA	NA	0.99	1.09
Adjusted char *	0.53	0.55	0.58	0.53	0.54	0.54	0.68	0.69	NA	NA	0.79	0.87
2E + 1.25AC	1.12	1.25	1.28	1.28	1.31	1.28	1.19	1.12	NA	NA	0.99	1.09
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.27	0.20	0.23	0.29	0.32	0.41	0.59	0.75	NA	NA	0.70	0.56
45 degrees												
Measured Erosion	0.19	0.23	0.25	0.25	0.26	0.26	0.17	0.16	NA	0.00	0.01	0.00
Measured Char	0.71	0.65	0.67	0.75	0.71	0.70	0.77	0.77	NA	0.95	0.82	0.93
Adjusted char *	0.57	0.52	0.54	0.60	0.57	0.56	0.62	0.62	NA	0.76	0.66	0.74
2E + 1.25AC	1.09	1.11	1.17	1.25	1.23	1.22	1.11	1.09	NA	0.95	0.84	0.93
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.30	0.35	0.35	0.32	0.41	0.48	0.70	0.80	NA	0.76	1.01	0.83
90 degrees												
Measured Erosion	0.10	0.15	0.20	0.26	0.24	NA	NA	NA	NA	0.05	0.03	0.03
Measured Char	0.66	0.65	0.71	0.60	0.64	NA	NA	NA	NA	0.98	0.96	1.00
Adjusted char *	0.53	0.52	0.57	0.48	0.51	NA	NA	NA	NA	0.78	0.77	0.80
2E + 1.25AC	0.86	0.95	1.11	1.12	1.12	NA	NA	NA	NA	1.08	1.02	1.06
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.65	0.58	0.42	0.48	0.55	NA	NA	NA	NA	0.55	0.65	0.61
135 degrees												
Measured Erosion	0.10	0.20	0.24	0.25	0.26	0.17	0.14	0.13	NA	0.00	0.00	0.00
Measured Char	0.67	0.70	0.67	0.69	0.66	0.77	0.82	0.89	NA	1.01	0.91	0.99
Adjusted char *	0.54	0.56	0.54	0.55	0.53	0.62	0.66	0.71	NA	0.81	0.73	0.79
2E + 1.25AC	0.87	1.10	1.15	1.19	1.18	1.11	1.10	1.15	NA	1.01	0.91	0.99
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.63	0.36	0.37	0.39	0.47	0.63	0.72	0.71	NA	0.66	0.85	0.72
160 degrees												
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	0.00	0.02
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.92	0.96	0.94
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.74	0.77	0.75
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.92	0.96	0.98
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.82	0.76	0.74

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

Table 4.5 (continued)
STS-27A Cowl/OBR Erosion and Char Data

Angular Location	Stations											
180 degrees	0	1	2	3	4	5	6	7	8	9	10	11.3
Measured Erosion	0.14	0.19	0.21	0.24	0.26	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.67	0.66	0.65	0.70	0.69	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.54	0.53	0.52	0.56	0.55	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	0.95	1.04	1.07	1.18	1.21	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.49	0.44	0.47	0.40	0.43	NA	NA	NA	NA	NA	NA	NA
225 degrees												
Measured Erosion	0.16	0.20	0.24	0.26	0.22	0.20	0.17	0.15	NA	0.00	0.03	0.01
Measured Char	0.68	0.69	0.67	0.68	0.73	0.80	0.85	0.90	NA	0.87	0.87	0.92
Adjusted char *	0.54	0.55	0.54	0.54	0.58	0.64	0.68	0.72	NA	0.70	0.70	0.74
2E + 1.25AC	1.00	1.09	1.15	1.20	1.17	1.20	1.19	1.20	NA	0.87	0.93	0.94
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.42	0.38	0.37	0.38	0.48	0.51	0.59	0.64	NA	0.93	0.81	0.81
270 degrees												
Measured Erosion	0.18	0.25	0.28	0.26	0.28	0.20	0.17	NA	NA	0.08	0.06	0.04
Measured Char	0.67	0.67	0.68	0.70	0.68	0.71	0.79	NA	NA	0.89	0.89	0.95
Adjusted char *	0.54	0.54	0.54	0.56	0.54	0.57	0.63	NA	NA	0.71	0.71	0.76
2E + 1.25AC	1.03	1.17	1.24	1.22	1.24	1.11	1.13	NA	NA	1.05	1.01	1.03
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.38	0.28	0.27	0.36	0.40	0.63	0.67	NA	NA	0.60	0.67	0.65
300 degrees												
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02	0.02	0.03
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.97	0.93	0.99
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.78	0.74	0.79
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.01	0.97	1.05
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.66	0.74	0.62
315 degrees												
Measured Erosion	0.16	0.22	0.24	0.25	0.28	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.73	0.74	0.73	0.74	0.75	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.58	0.59	0.58	0.59	0.60	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.05	1.18	1.21	1.24	1.31	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.417	1.499	1.577	1.655	1.733	1.811	1.889	1.963	1.597	1.675	1.687	1.704
Margin of Safety	0.35	0.27	0.30	0.33	0.32	NA	NA	NA	NA	NA	NA	NA

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \text{ X erosion} + 1.25 \text{ X adj char*}} - 1$$

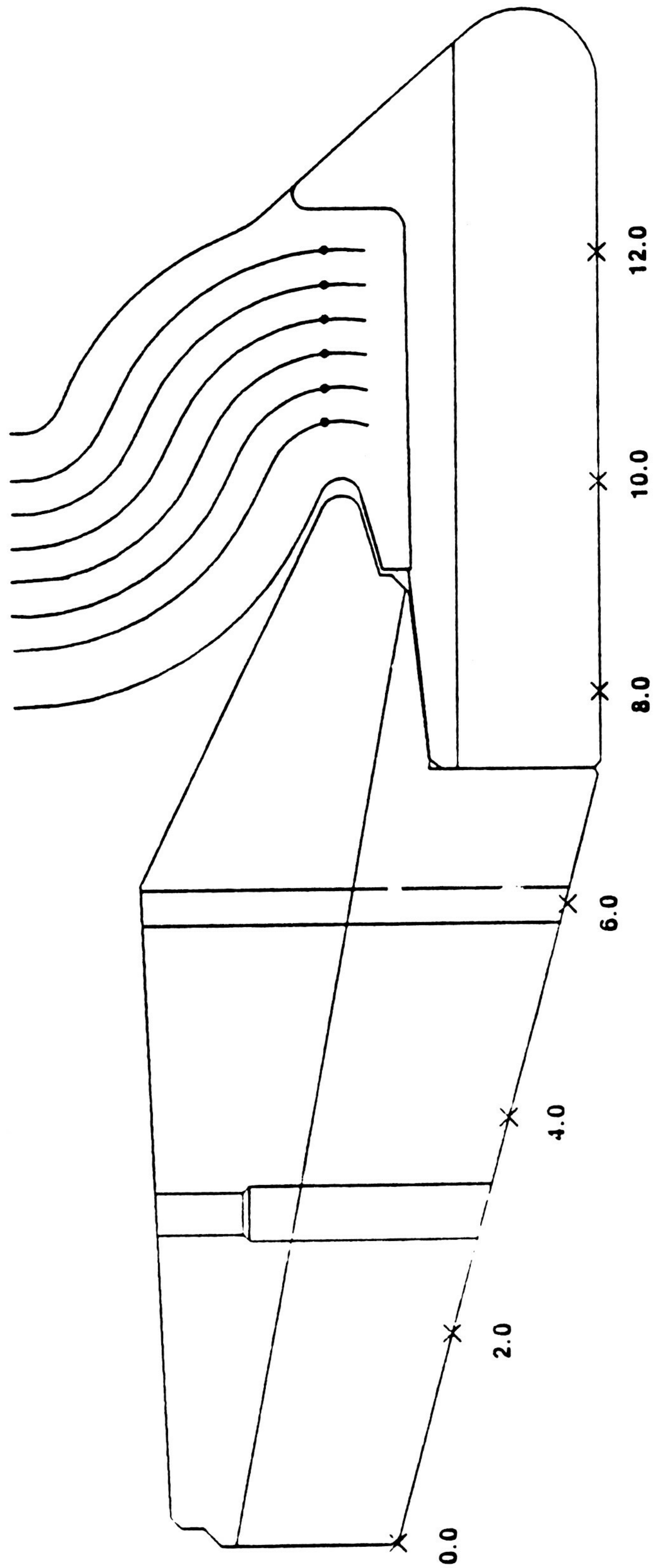
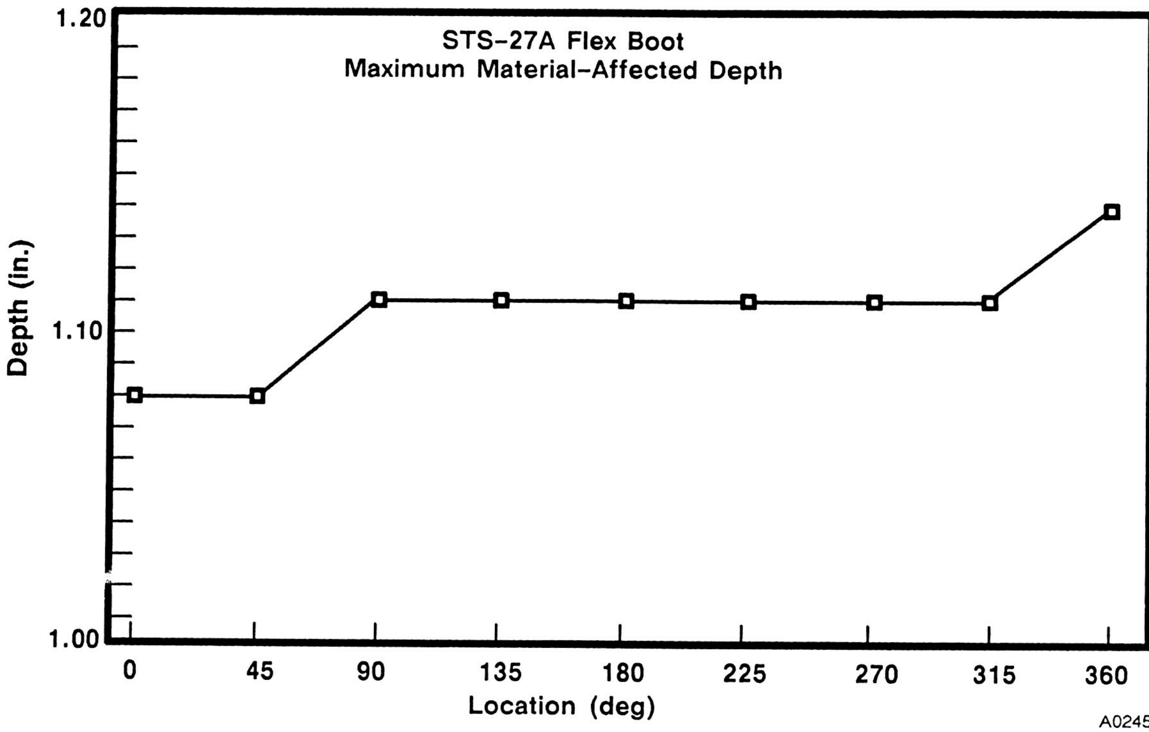


Figure 4.40 Cowl Ring and Outer Boot Ring Erosion Measurement Stations



Location (deg)	Remaining Plies	Maximum Material-Affected Depth	Performance Margin of Safety
0	4.0	1.08	0.54
45	4.0	1.08	0.54
90	3.9	1.11	0.50
135	3.9	1.11	0.50
160	3.9	1.11	0.50
225	3.9	1.11	0.50
260	3.9	1.11	0.50
300	3.8	1.14	0.46

$$PMS = \frac{\text{Minimum Design Thickness}}{1.5\ (\text{Maximum Material-Affected Depth})} - 1$$

Figure 4.41 STS-27A Flex Boot Performance

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Figure 4.42 STS-27A Fixed Housing Fwd End Post-Burn Wedgeout of Charred CCP (198 degrees)

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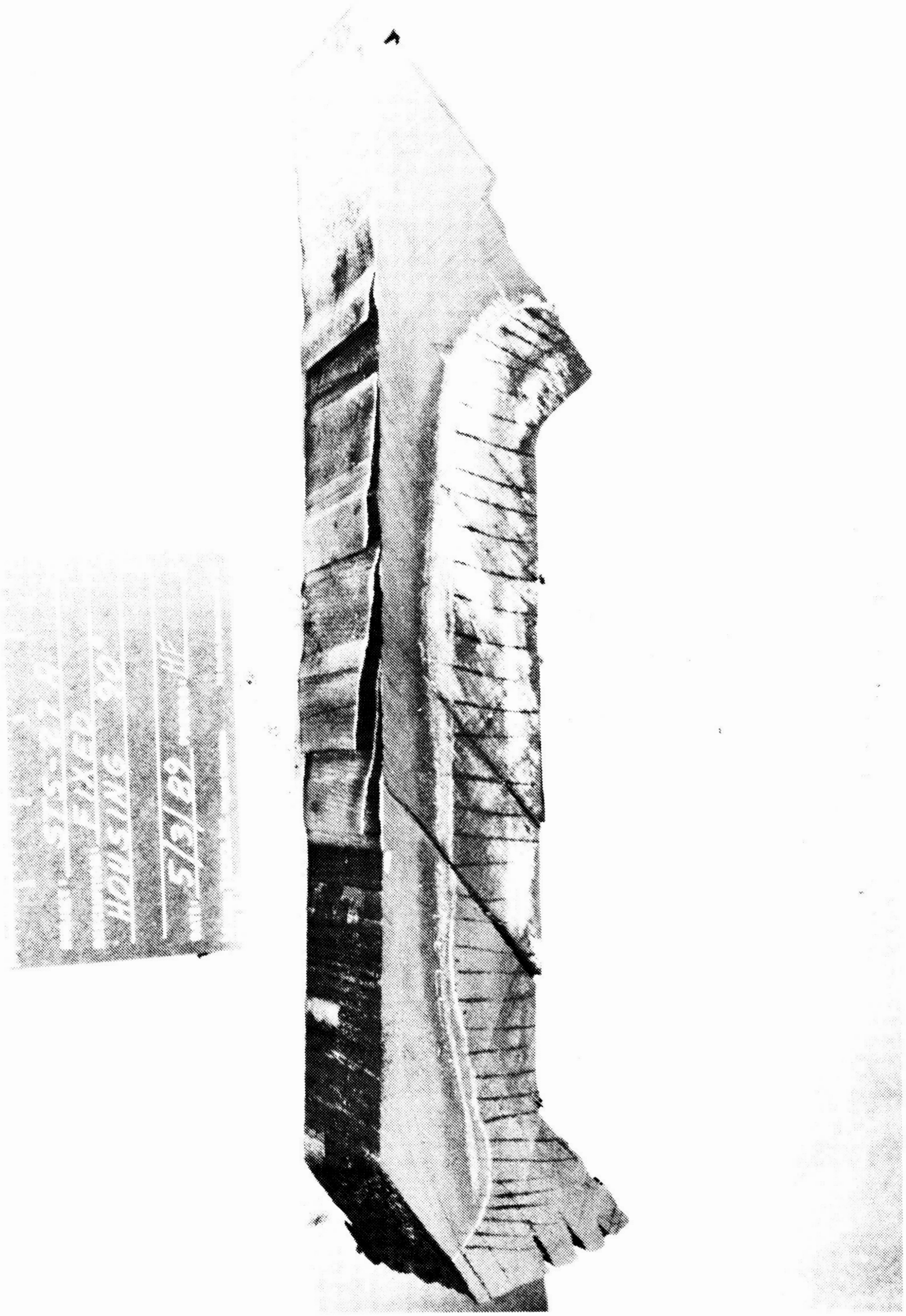

Figure 4.43 STS-27A Fixed Housing Insul. Sectioned View (90 degrees)

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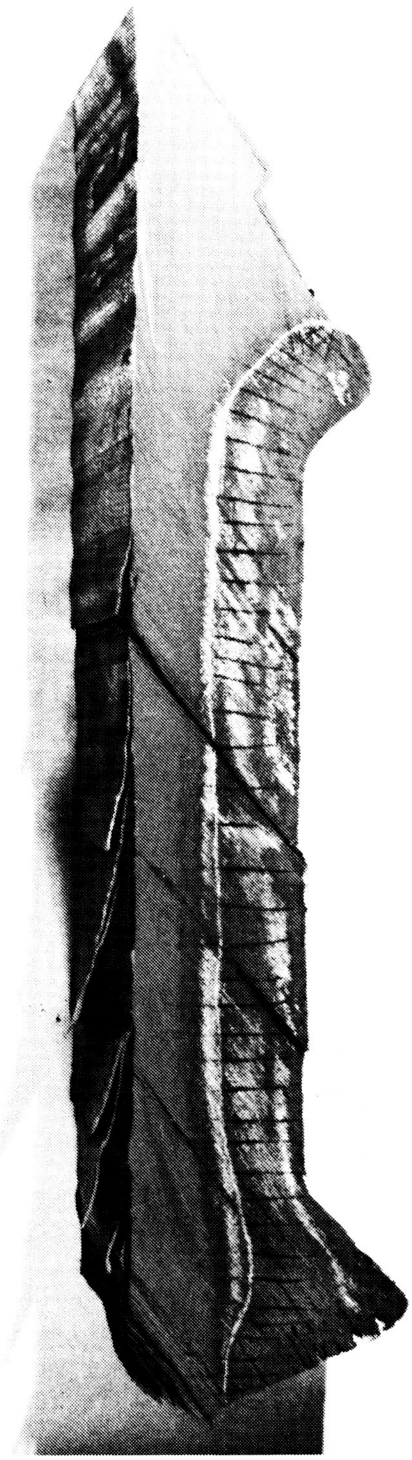

Figure 4.44 STS-27A Fixed Housing Insul. Sectioned View (270 degrees)

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Table 4.6

STS-27A Fixed Housing Insulation Erosion and Char Data

Angular Location	Stations										
	0	1	2	3	4	5	6	7	8	9	11
0 degrees											
Measured Erosion	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Measured Char	1.06	1.12	1.07	1.08	1.01	1.02	1.00	0.97	0.94	0.90	1.83
Adjusted Char*	0.85	0.90	0.86	0.86	0.81	0.82	0.80	0.78	0.75	0.72	1.46
2E + 1.25AC	1.22	1.18	1.07	1.08	1.01	1.02	1.00	0.97	0.94	1.02	1.83
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.22	0.74	0.68	0.67	0.80	0.79	0.83	0.89	0.96	1.46	0.72
90 degrees											
Measured Erosion	0.05	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.00
Measured Char	1.12	1.15	1.06	1.07	1.05	1.04	1.03	1.05	0.87	0.82	1.89
Adjusted Char*	0.90	0.92	0.85	0.86	0.84	0.83	0.82	0.84	0.70	0.66	1.51
2E + 1.25AC	1.22	1.21	1.06	1.07	1.07	1.04	1.03	1.05	0.87	0.92	1.89
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.22	0.70	0.70	0.69	0.70	0.75	0.77	0.75	1.11	1.73	0.66
180 degrees											
Measured Erosion	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
Measured Char	1.08	1.05	1.04	1.09	1.00	0.98	0.94	0.93	0.85	0.95	NA
Adjusted Char*	0.86	0.84	0.83	0.87	0.80	0.78	0.75	0.74	0.68	0.76	NA
2E + 1.25AC	1.14	1.07	1.04	1.09	1.00	0.98	0.94	0.93	0.85	0.95	NA
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.44	0.92	0.73	0.66	0.82	0.86	0.94	0.97	1.16	1.65	NA
270 degrees											
Measured Erosion	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Measured Char	1.02	1.05	1.00	1.03	0.97	0.99	0.94	0.95	0.91	0.89	1.77
Adjusted Char*	0.82	0.84	0.80	0.82	0.78	0.79	0.75	0.76	0.73	0.71	1.42
2E + 1.25AC	1.16	1.07	1.00	1.03	0.97	0.99	0.94	0.95	0.91	0.91	1.77
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.38	0.92	0.80	0.76	0.87	0.84	0.94	0.93	1.02	1.76	0.77

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \text{ X Erosion} + 1.25 \text{ X Adj Char*}} - 1$$

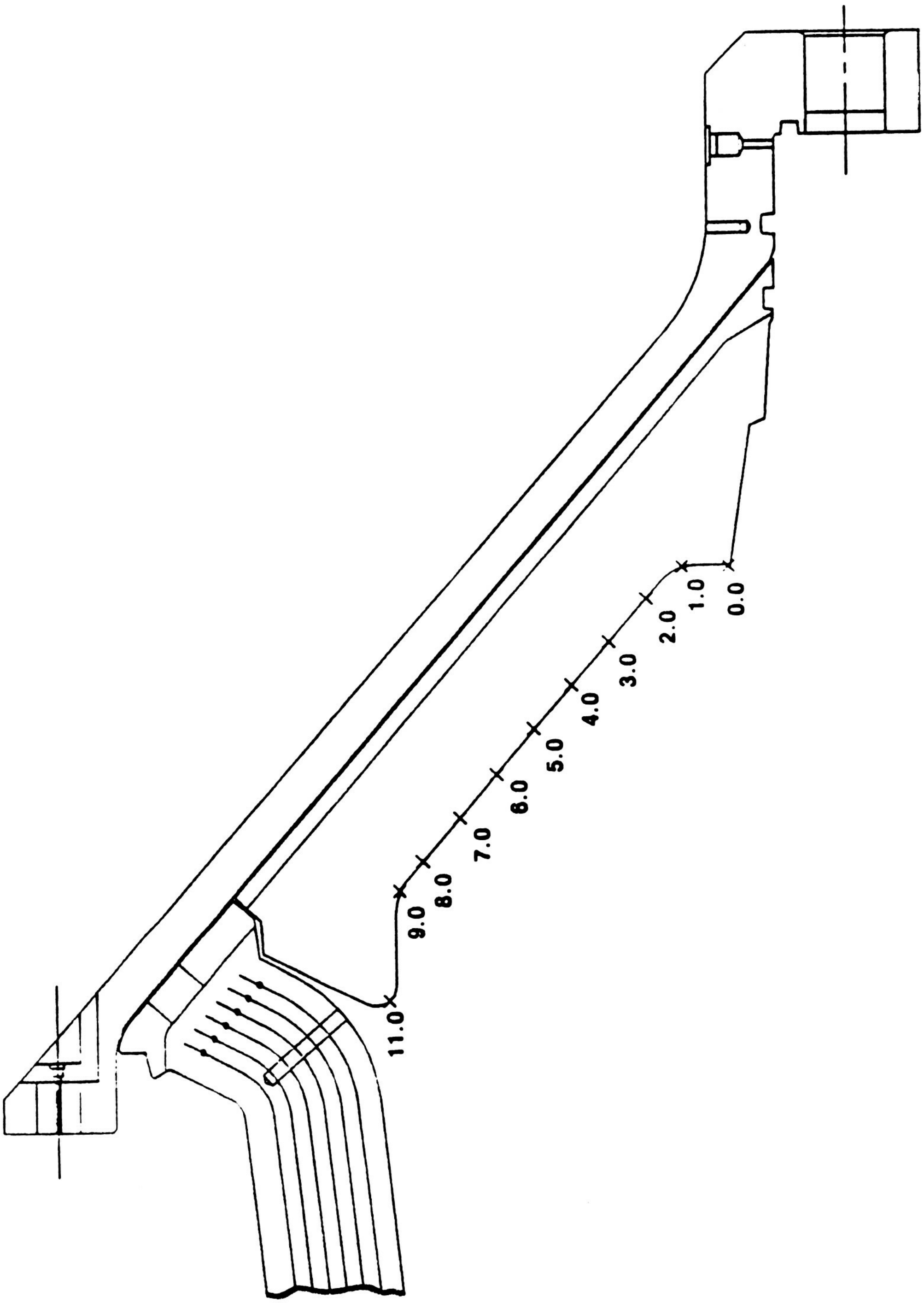

Figure 4.45 Fixed Housing Liner Erosion Measurement Station

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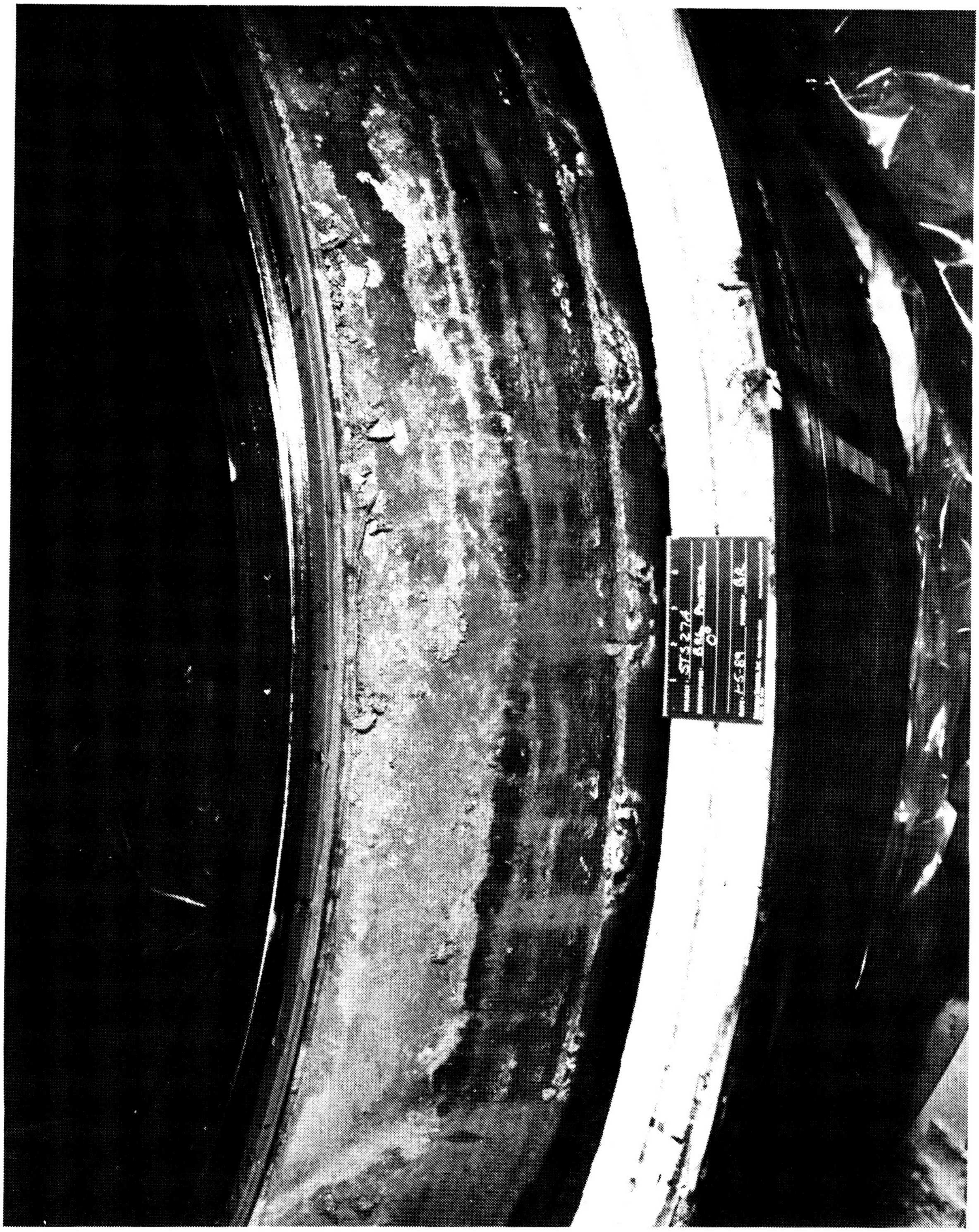

Figure 4.46 STS-27A Bearing Protector (0 degrees)

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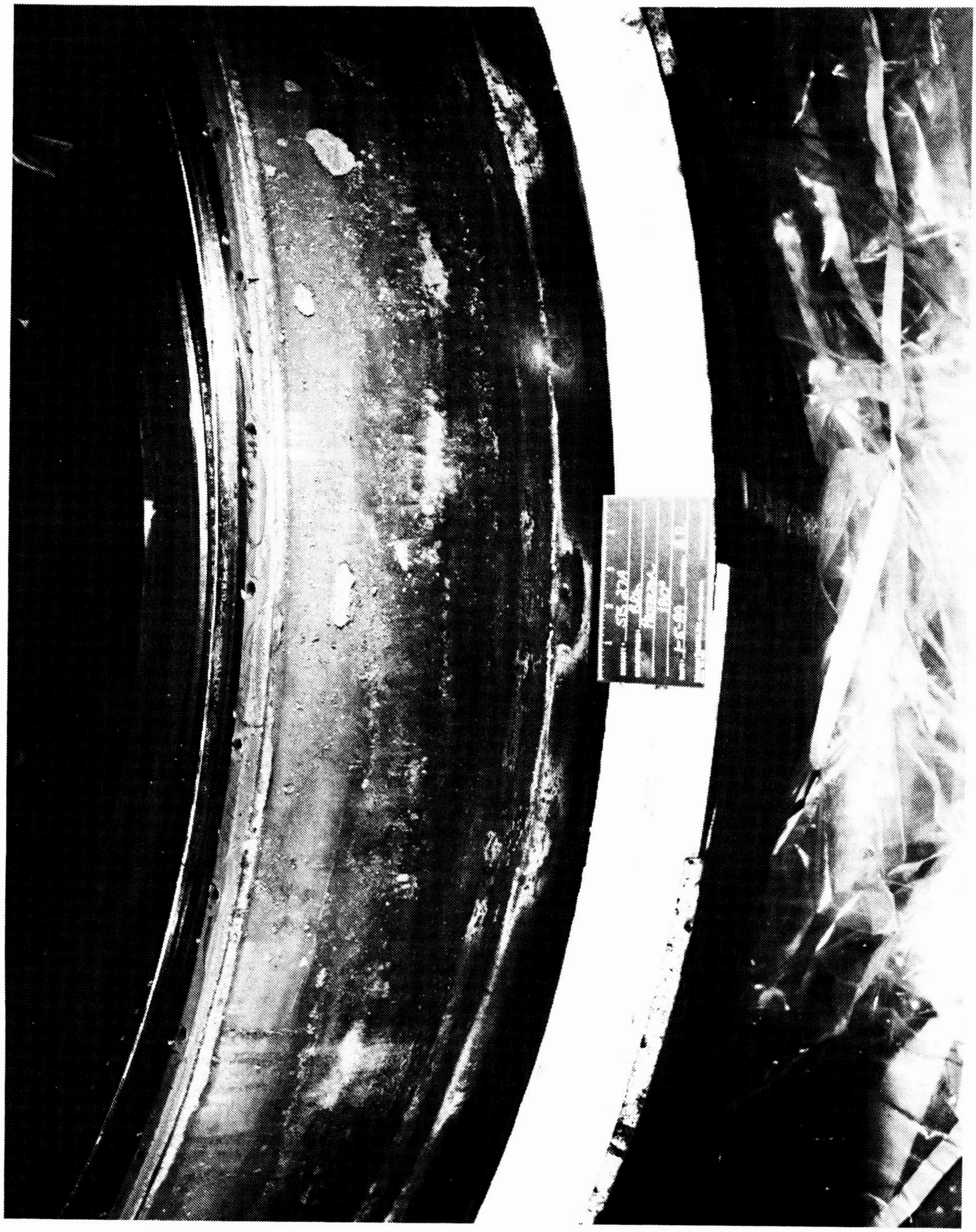

Figure 4.47 STS-27A Bearing Protector (180 degrees)

Circumferential Location (deg)	Erosion (in.)* In Line With Cowl Vent Holes
0	0.058
10	0.059
20	0.060
30	0.075
40	0.090
50	0.091
60	0.051
70	0.048
80	0.044
90	0.038
100	0.039
110	0.025
120	0.053
130	0.079
140	0.083
150	0.075
160	0.088
170	0.078
180	0.070
190	0.053
200	0.040
210	0.040
220	0.035
230	0.037
240	0.047
250	0.040
260	0.042
270	0.046
280	0.030
290	0.030
300	0.028
310	0.038
320	0.054
330	0.055
340	0.053
350	0.082

Figure 4.48 STS-27A Maximum Bearing Protector Erosion in Line with Cowl Vent Holes

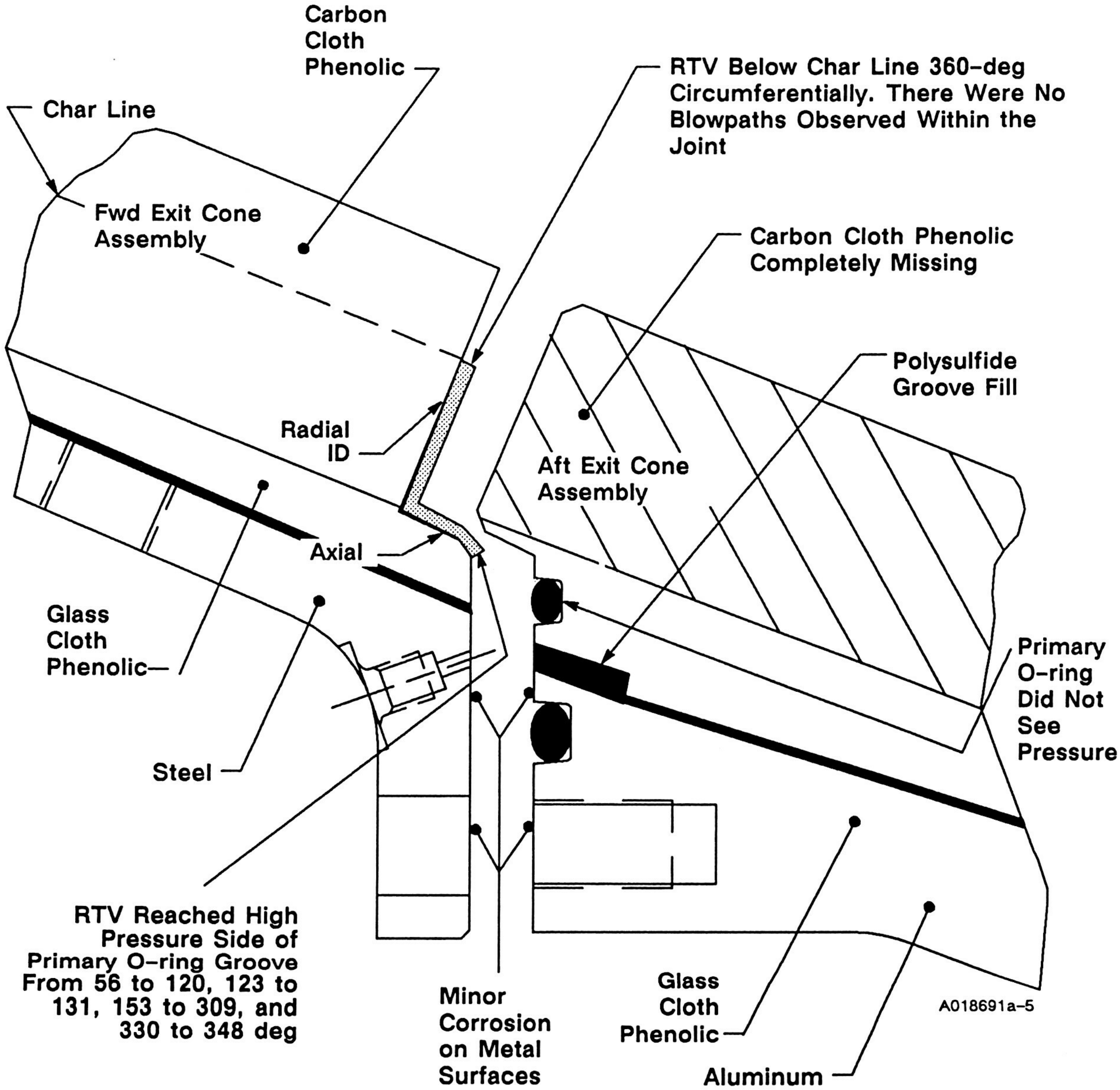

Figure 4.49 STS-27A Forward Exit Cone-to-Aft Exit Cone Interface

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Figure 4.50 STS-27A Aft Exit Cone Forward End Corrosion
(202.5 degrees)

Figure 4.51 STS-27A Forward Exit Cone Aft End Corrosion (30 degrees)

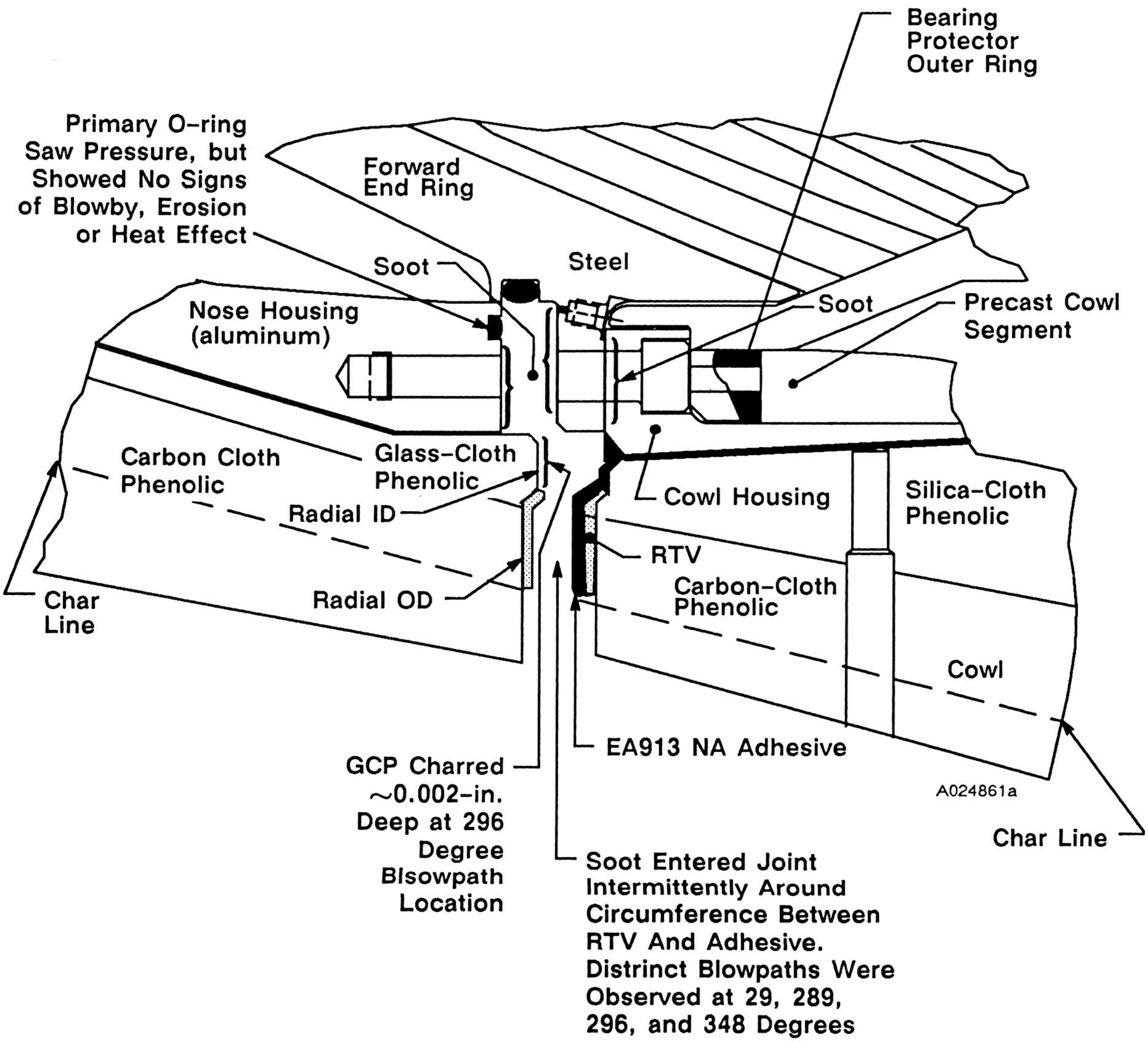

Figure 4.52. STS-27A Nose Inlet Housing/Flex Bearing Joint

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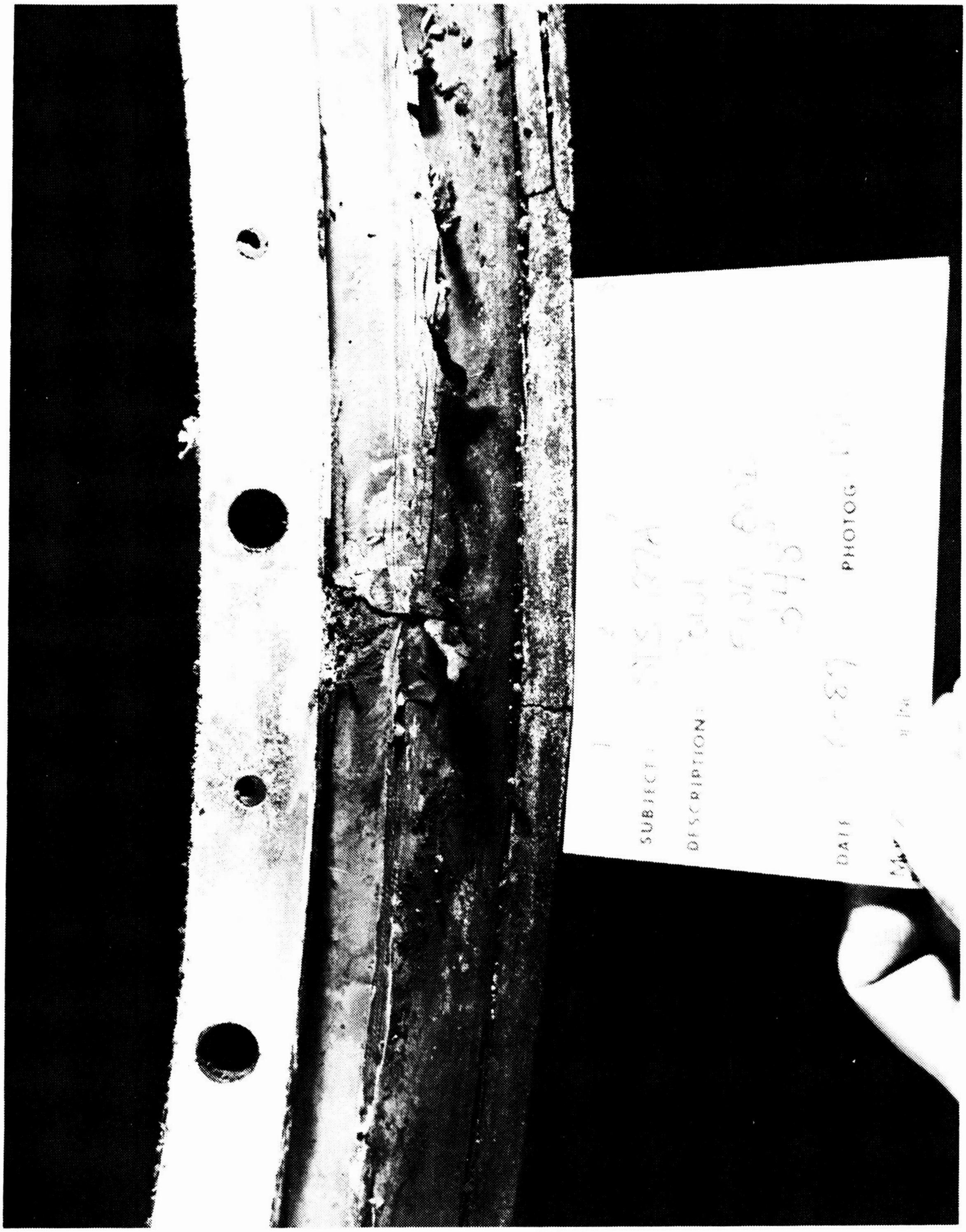

Figure 4.53 STS-27A Joint No. 2 Blowpath at 348 degrees

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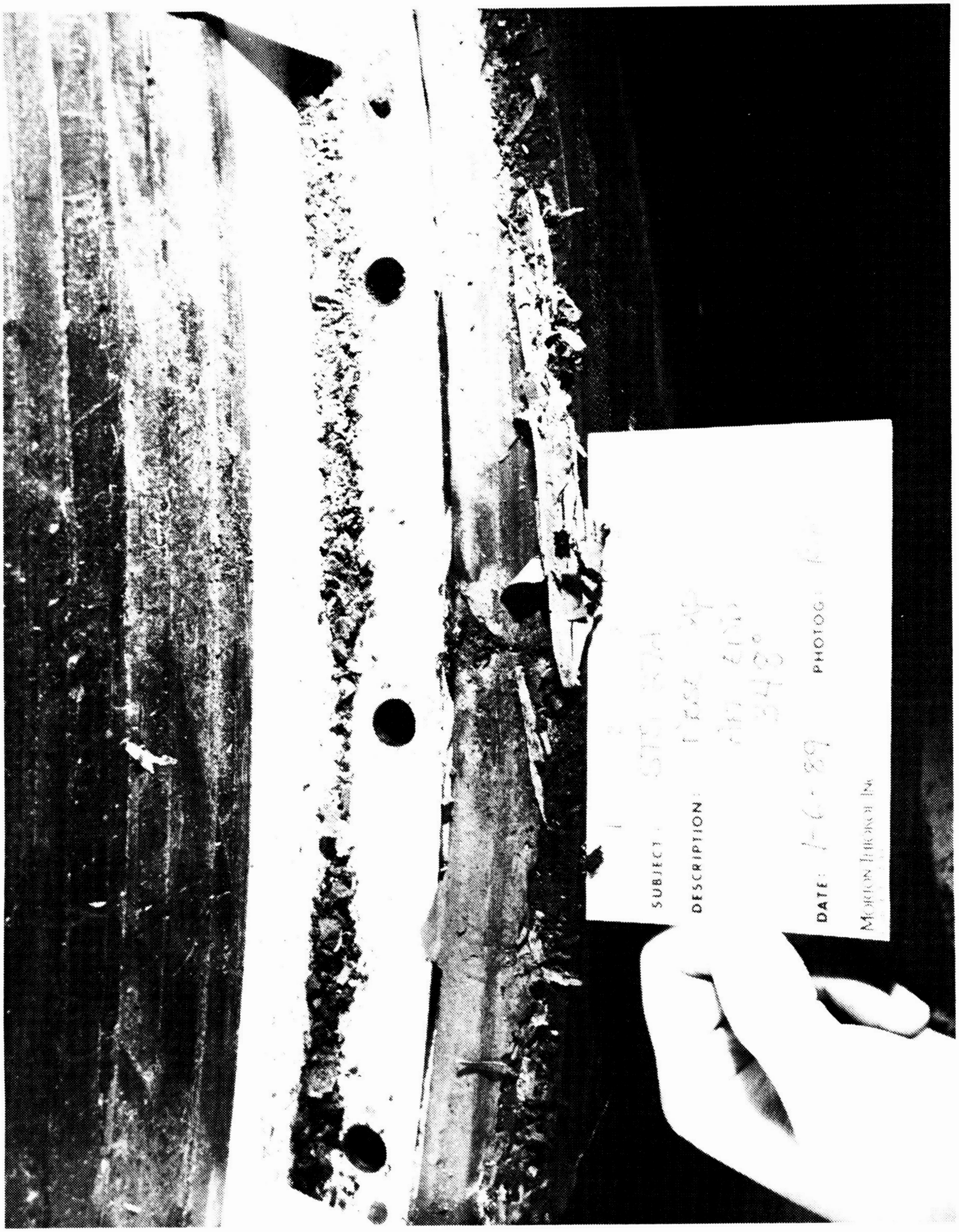

Figure 4.54 STS-27A Joint No. 2 Blowpath at 348 degrees

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Figure 4.55 STS-27A Joint No. 2 Blowpath at 348 degrees

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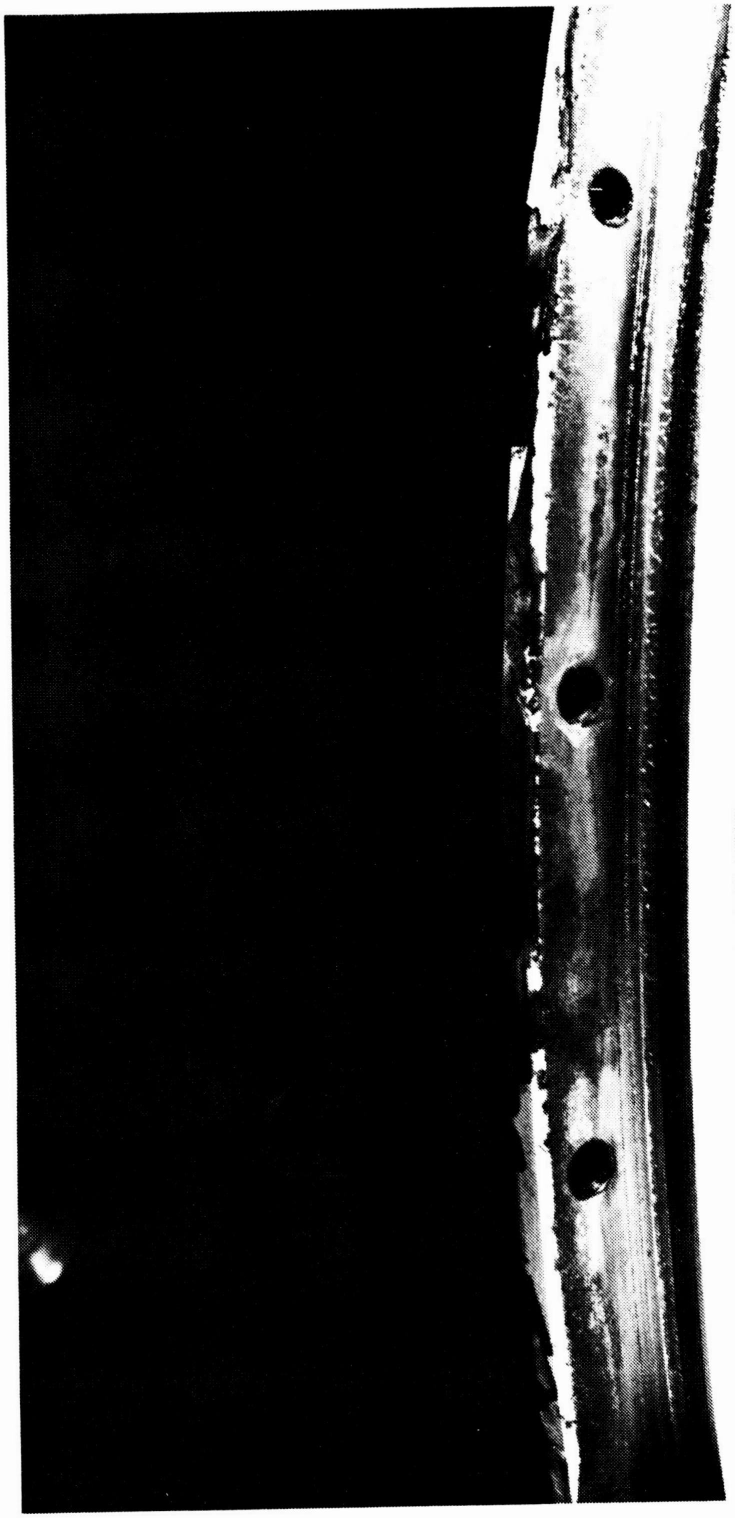

SUBJECT: STS 27A
DESCRIPTION: BRG
FWD END RING
345°
DATE: 1-6-89 PHOTOG: B.R.

Figure 4.56 STS-27A Joint No. 2 Blowpath at 348 degrees

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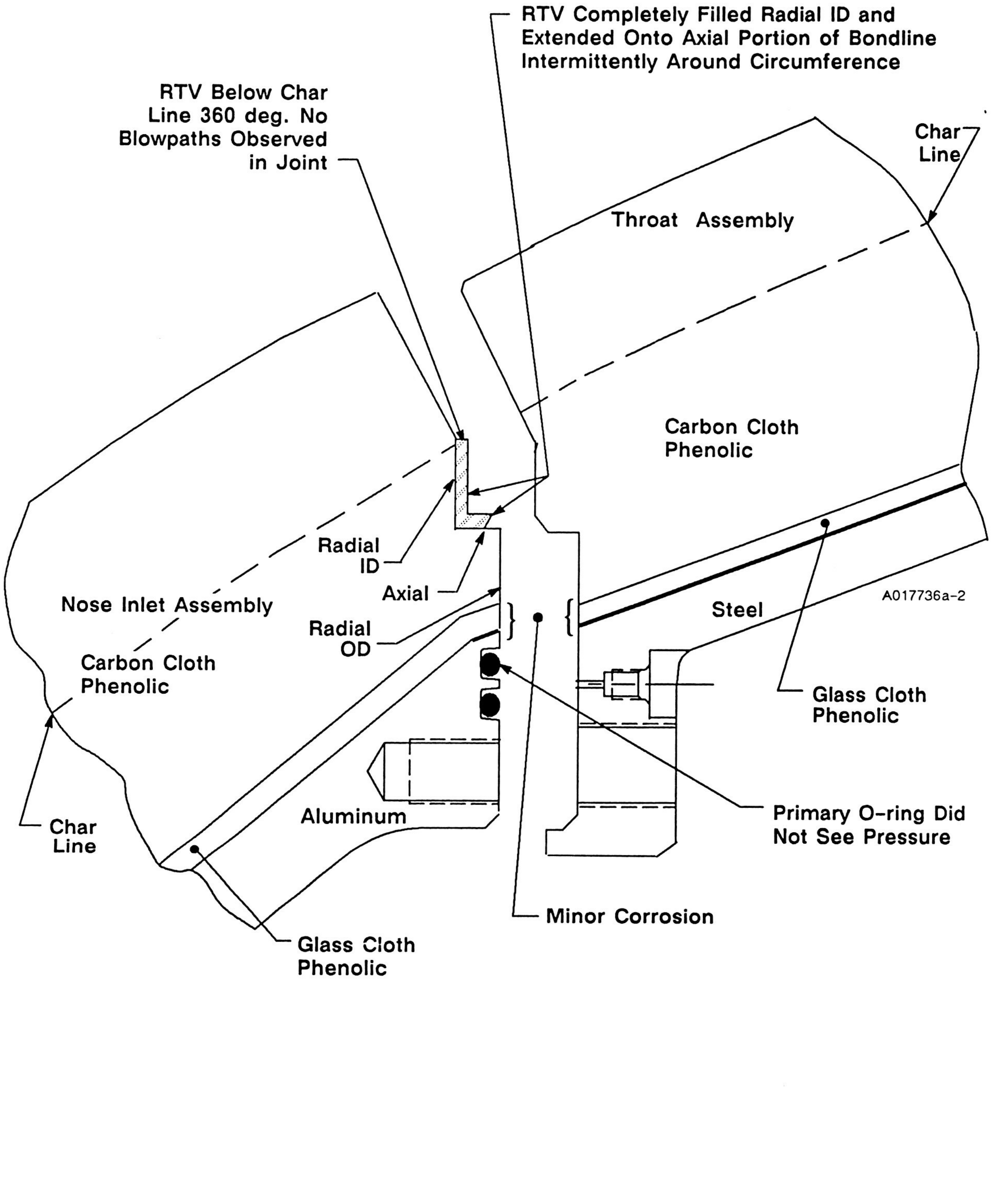

Figure 4.57 STS-27A Nose Inlet/Throat Housing Joint

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Figure 4.58 STS-27A Joint No. 3 -504 Aft End (300 degrees)

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Figure 4.59 STS-27A Joint No. 3 Throat Inlet Fwd End (300 degrees)

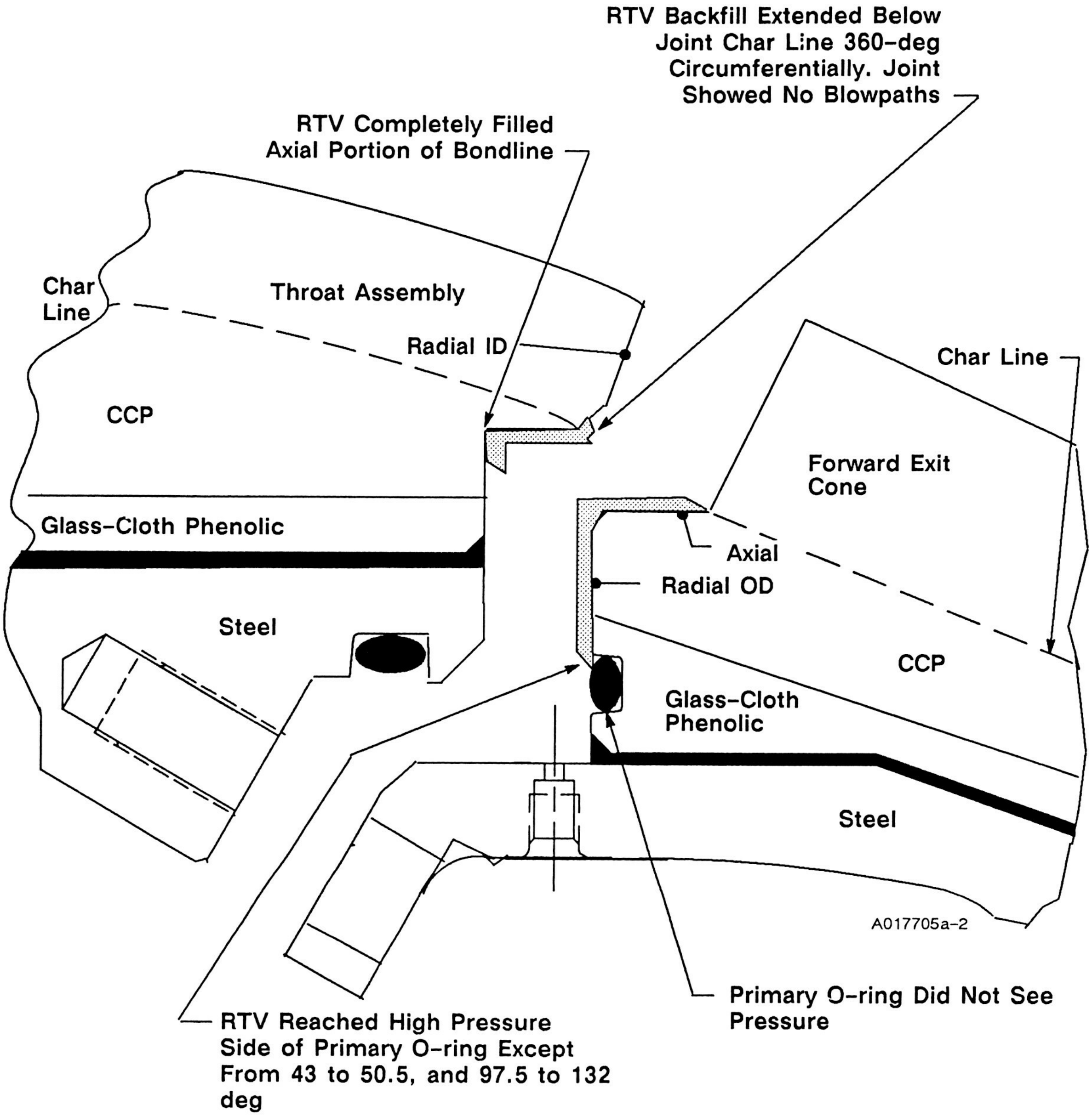

Figure 4.60 STS-27A Throat-to-Forward Exit Cone Joint

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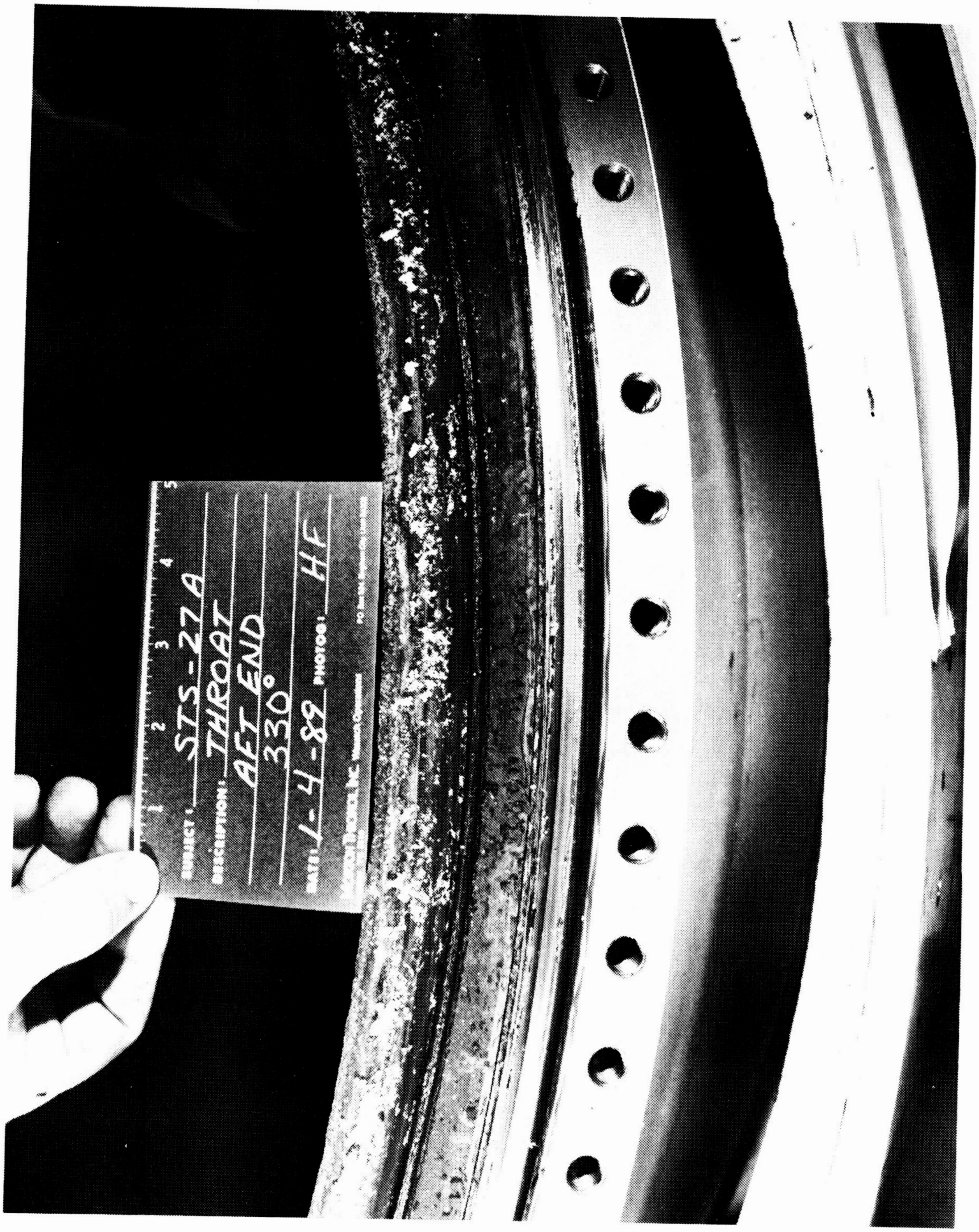

Figure 4.61 STS-27A Joint No. 4 Throat Aft End (330 degrees)

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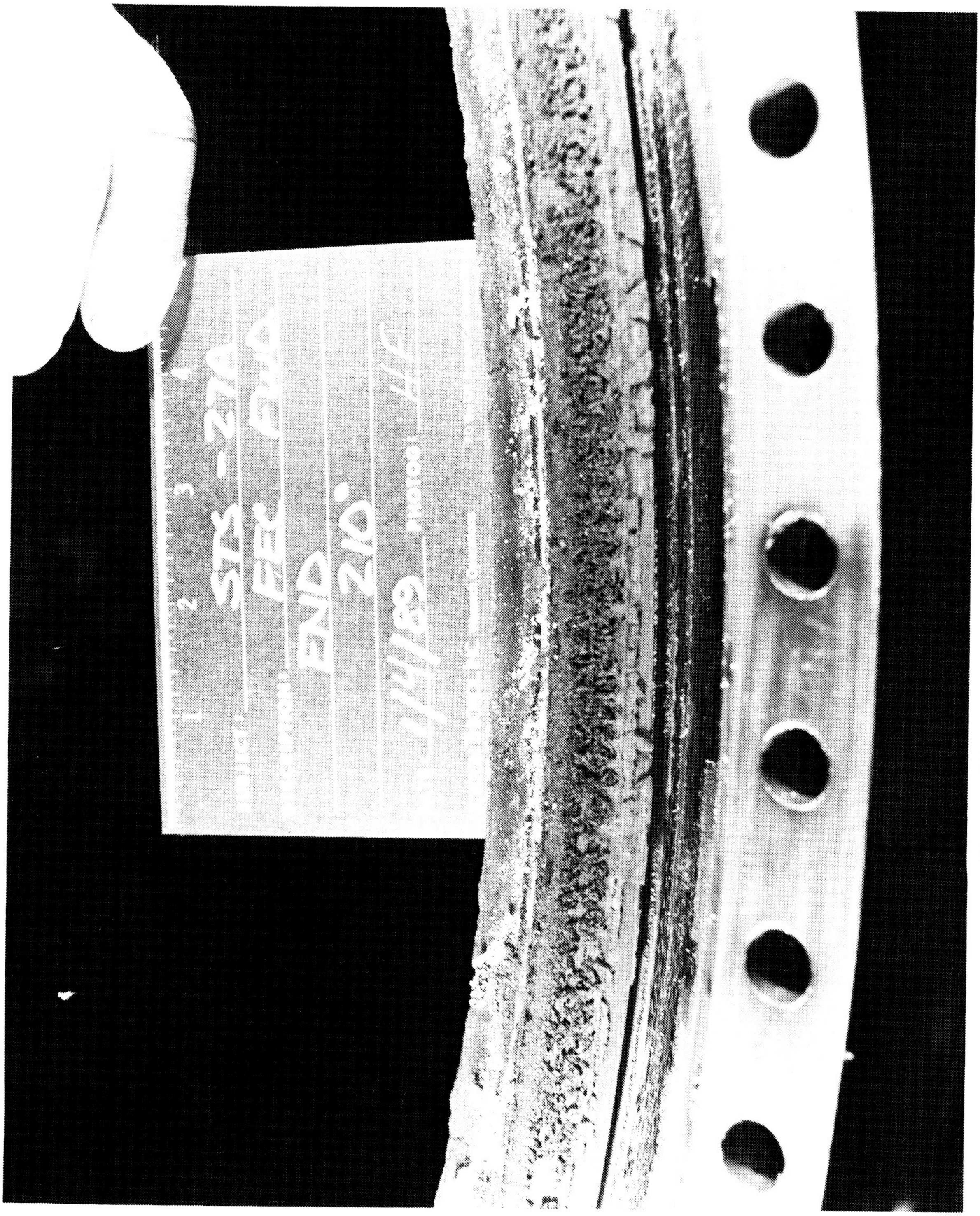

Figure 4.62 STS-27A Joint No. 4 Fwd Exit Cone Fwd End (210 degrees)

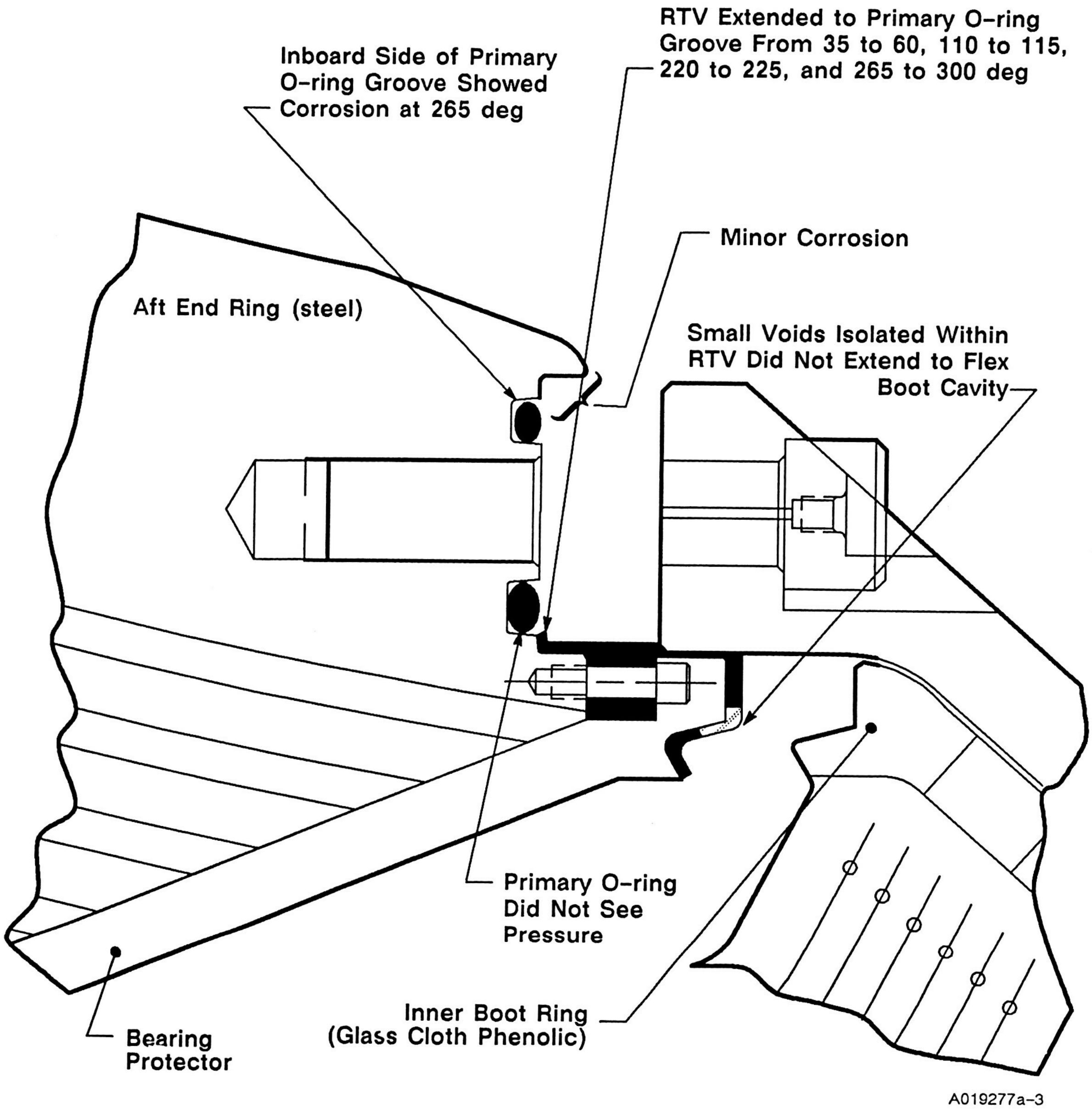

Figure 4.63 STS-27A Flex Bearing/Fixed Housing Joint

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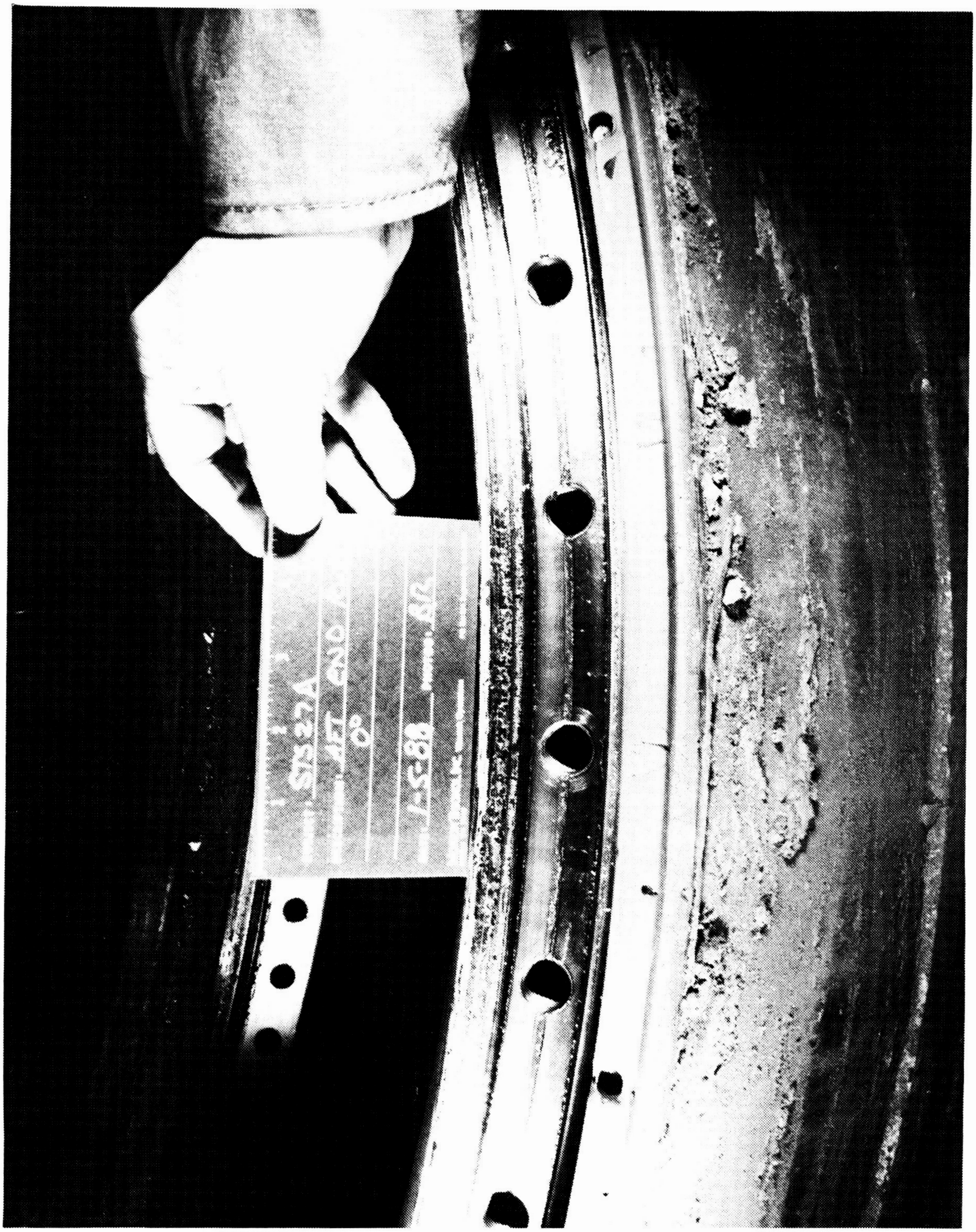

Figure 4.64 STS-27A Joint No. 5 Bearing Aft End Ring Aft End (0 degrees)

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Figure 4.65 STS-27A Joint No. 5 Fixed Housing Fwd End (0 degrees)

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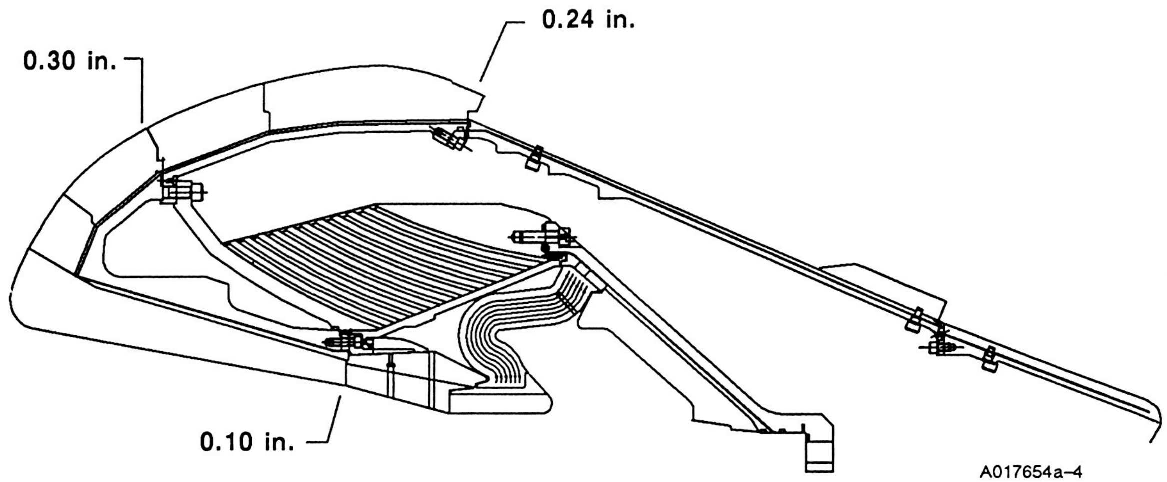

Figure 4.66 STS-27B Joint Flow Surface Gap Openings

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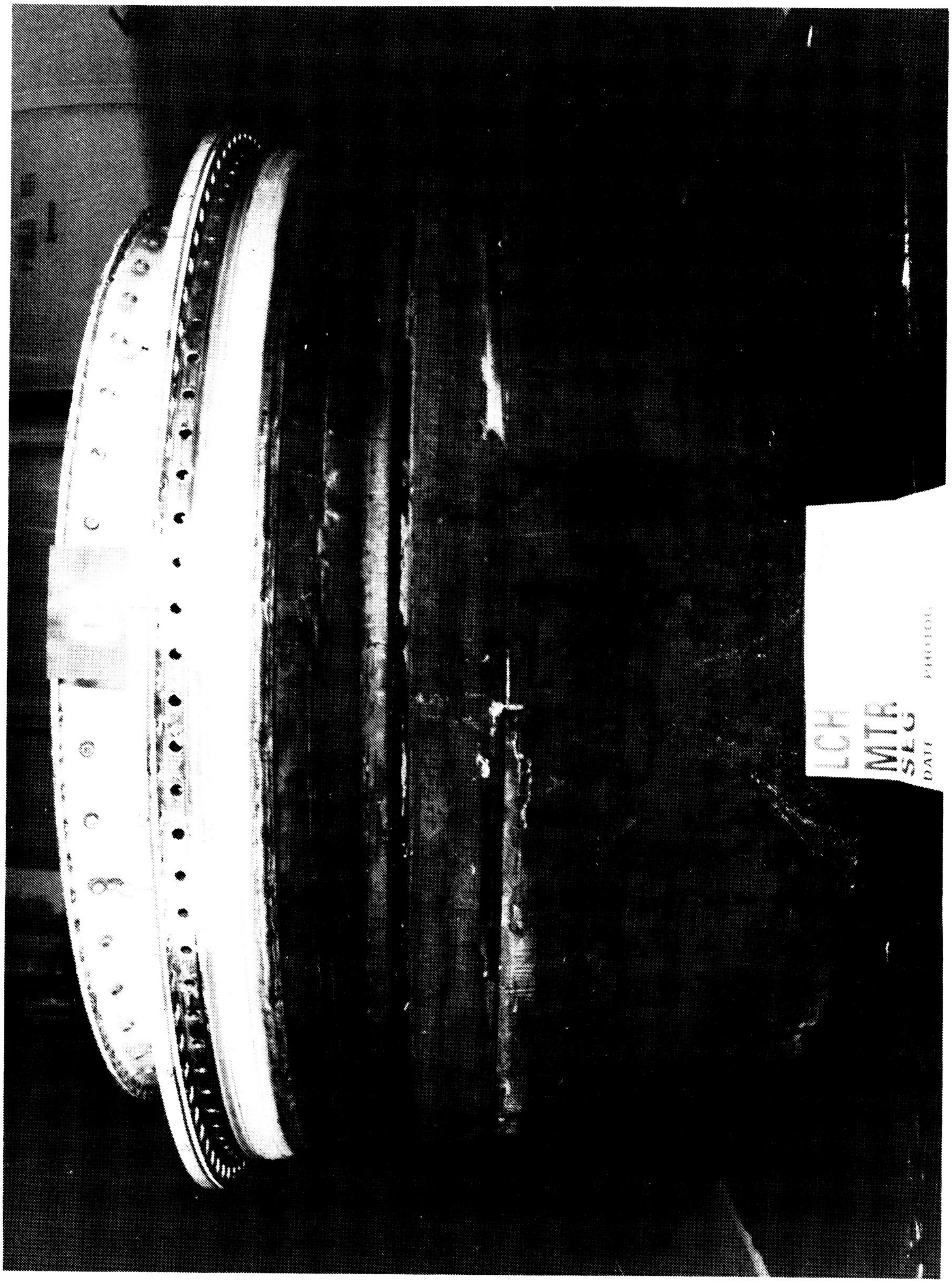

Figure 4.67 STS-27B Nozzle Overall View (0 degrees)

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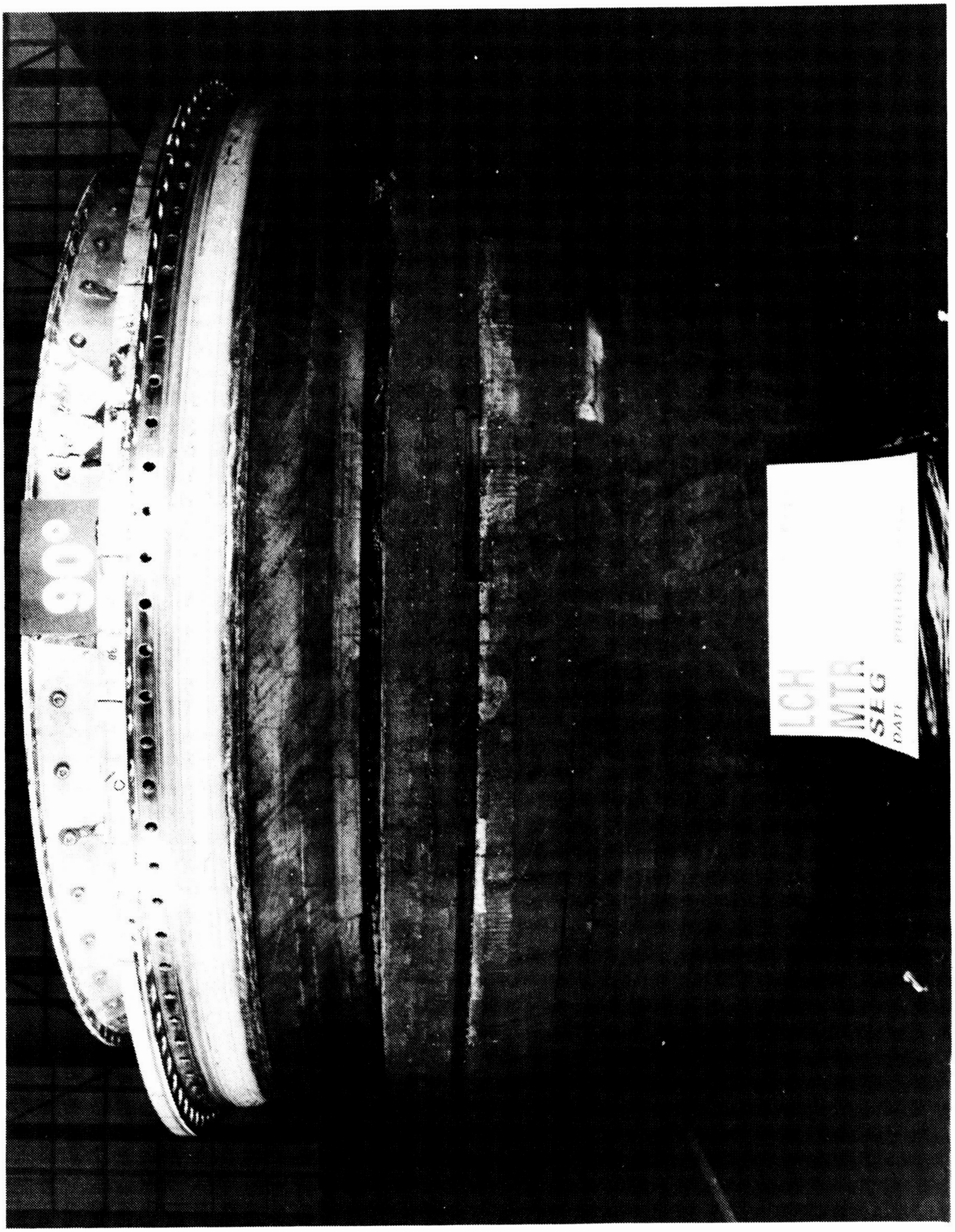

Figure 4.68 STS-27B Nozzle Overall View (90 degrees)

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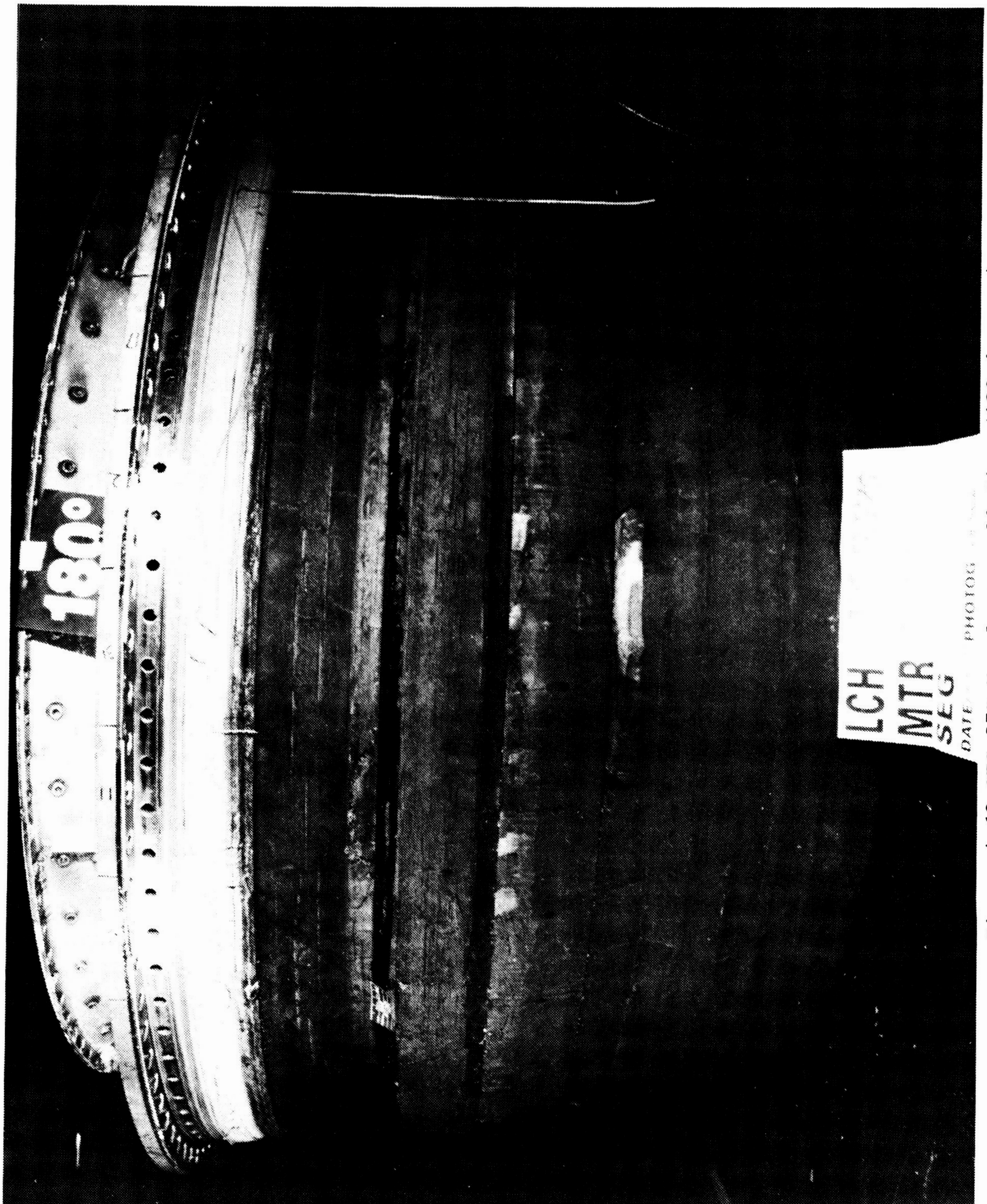

Figure 4.69 STS-27B Nozzle Overall View (180 degrees)

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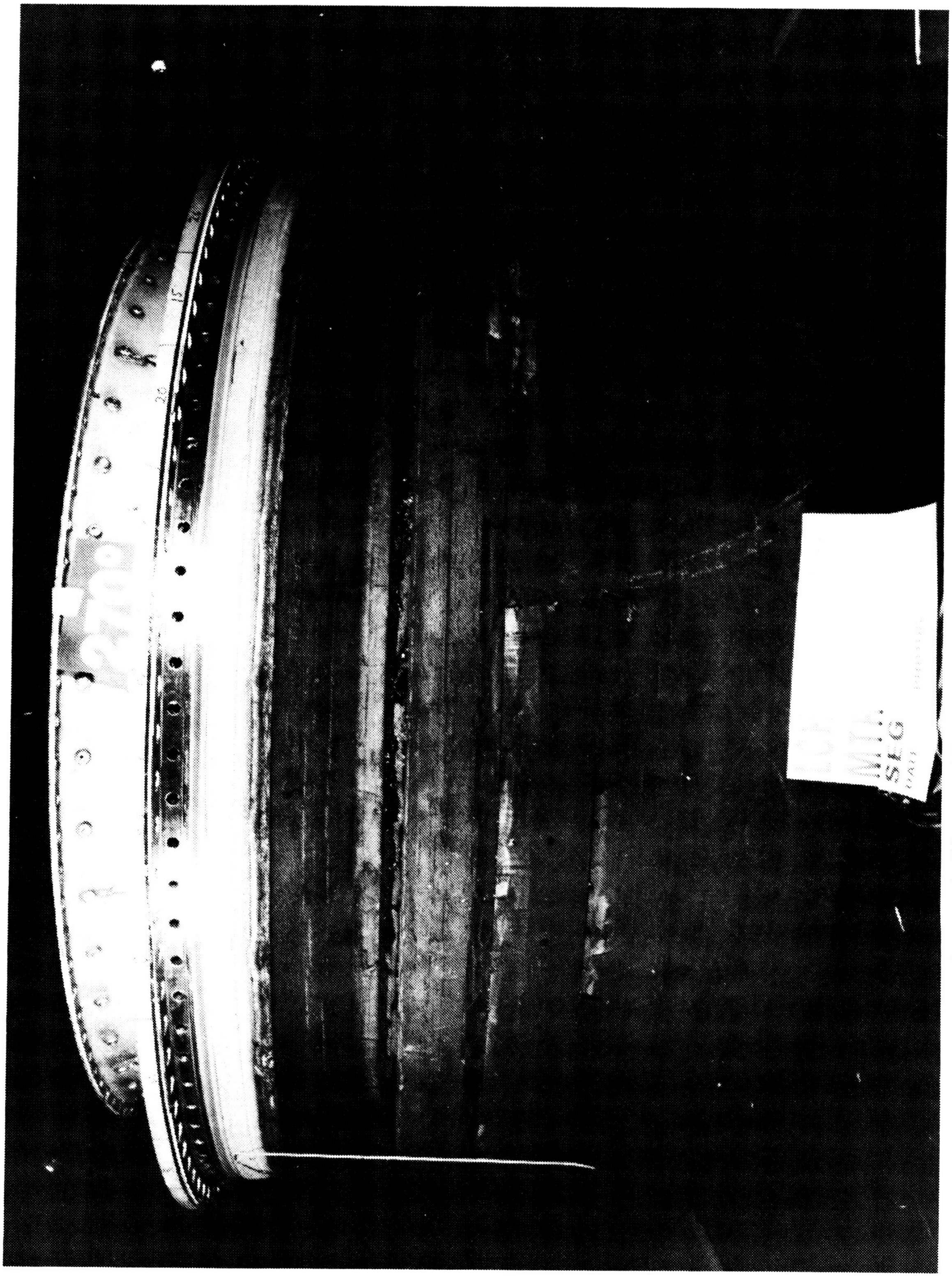

Figure 4.70 STS-27B Nozzle Overall View (270 degrees)

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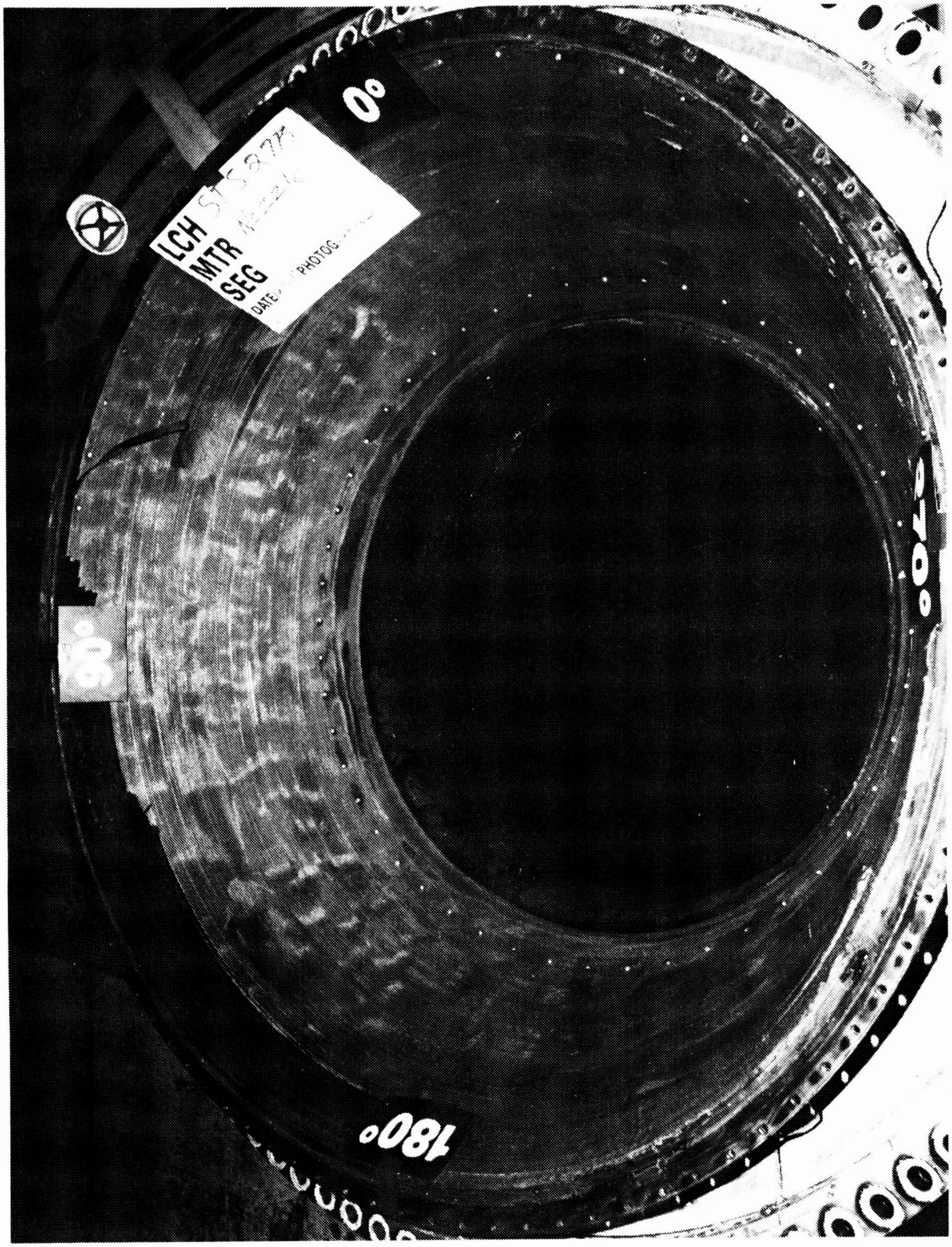

Figure 4.71 STS-27B Nozzle Internal View (0-180 degrees)

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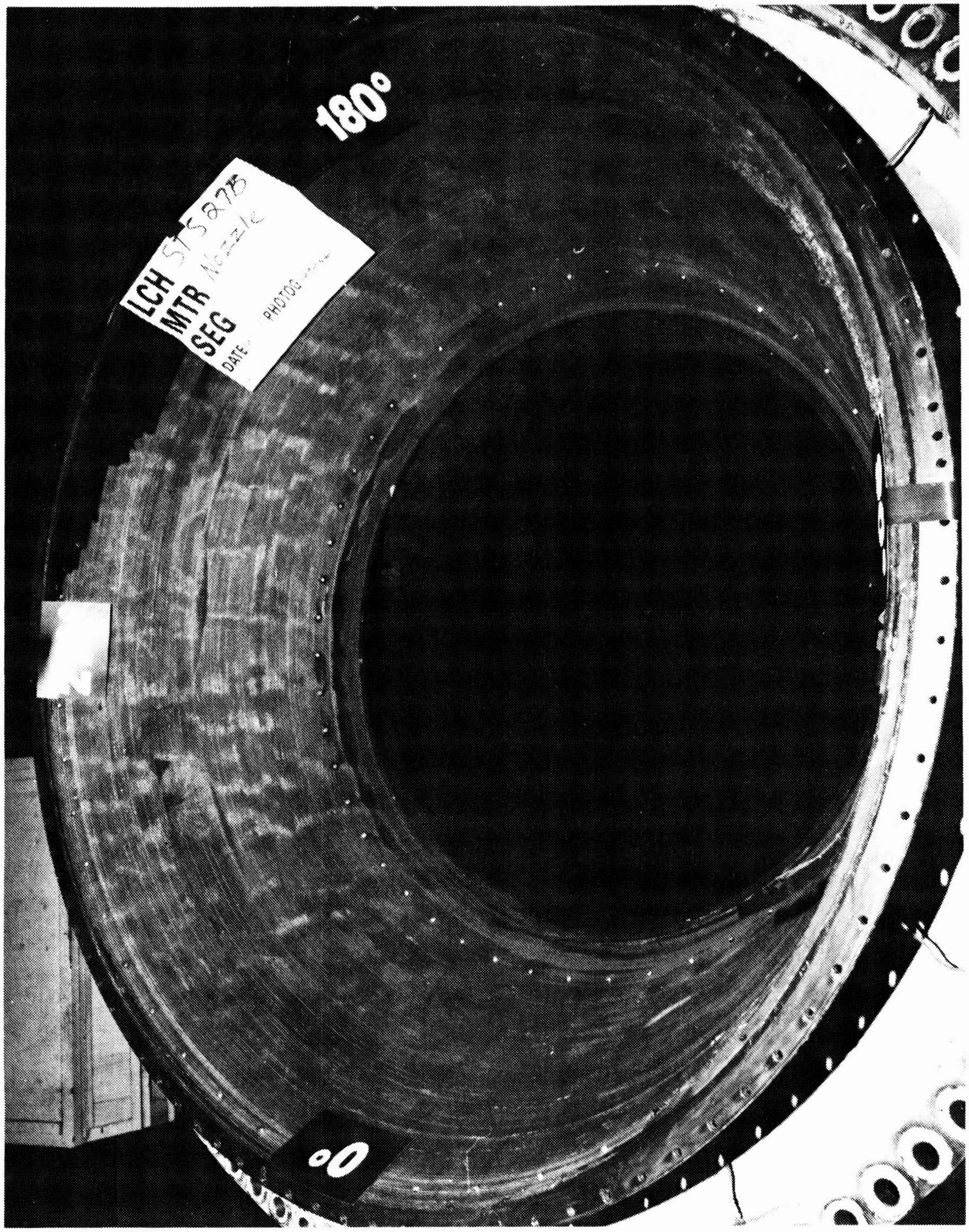

Figure 4.72 STS-27B Nozzle Internal View (180-360 degrees)

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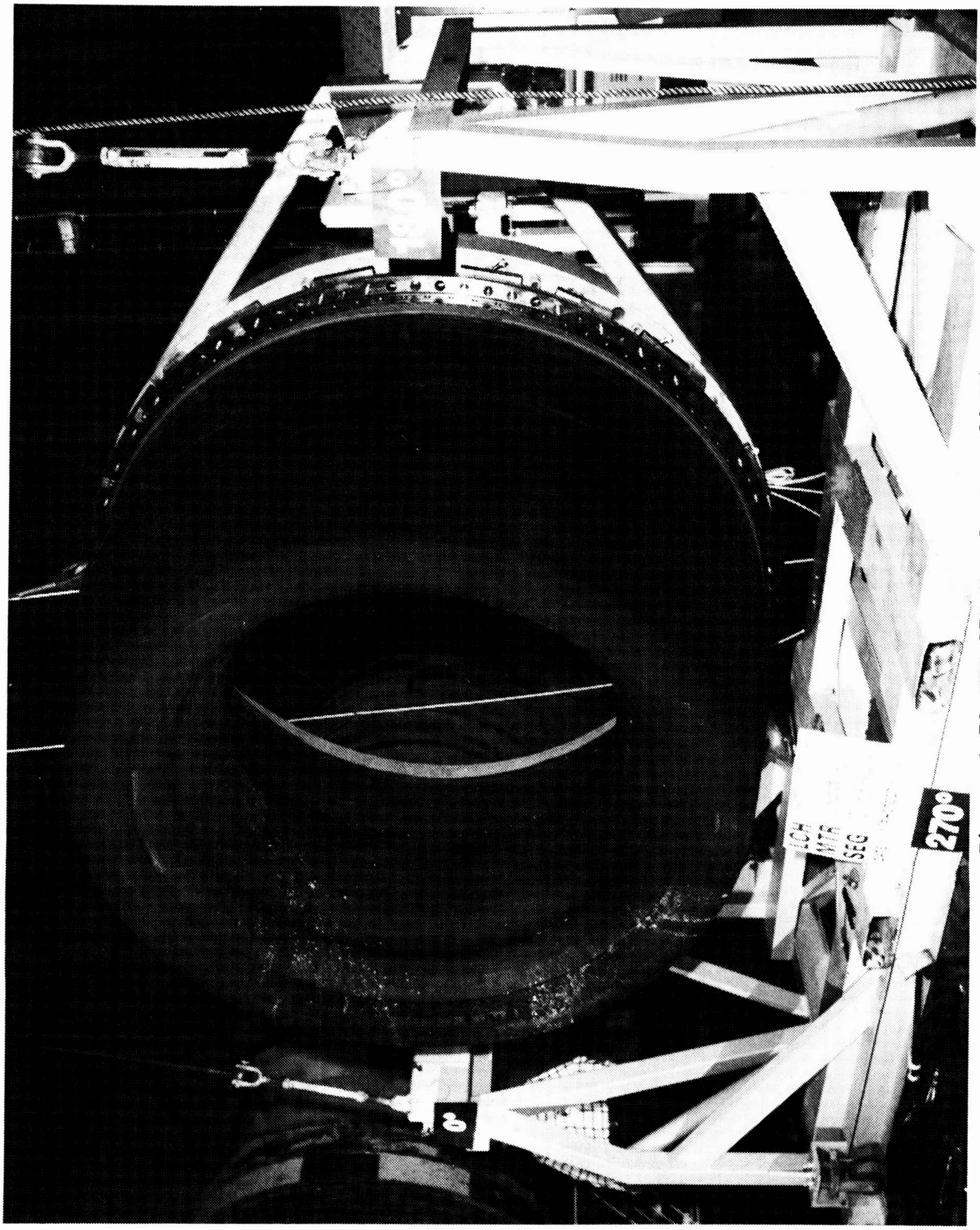

Figure 4.73 STS-27B Nozzle Overall View

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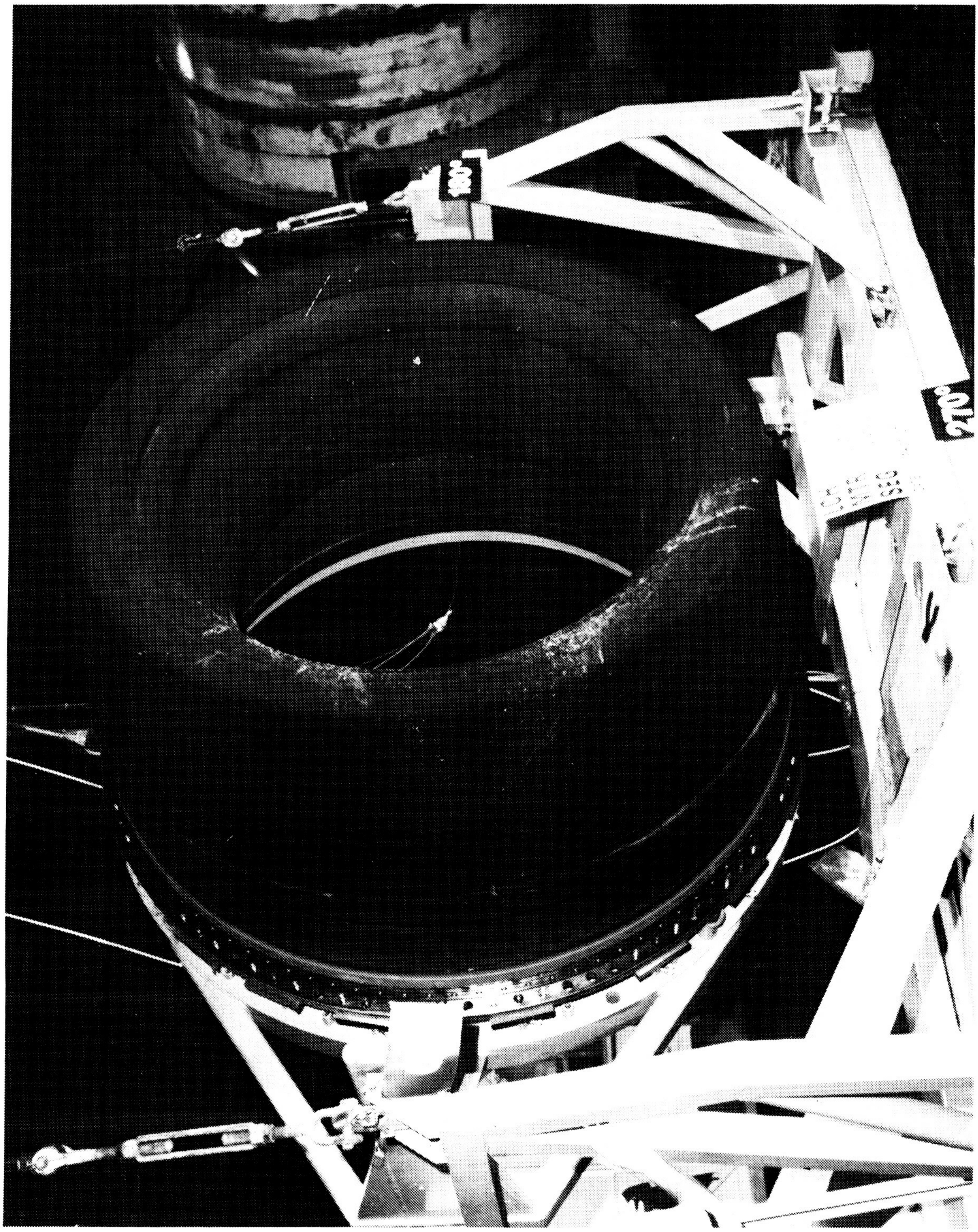

Figure 4.74 STS-27B Nozzle Overall View

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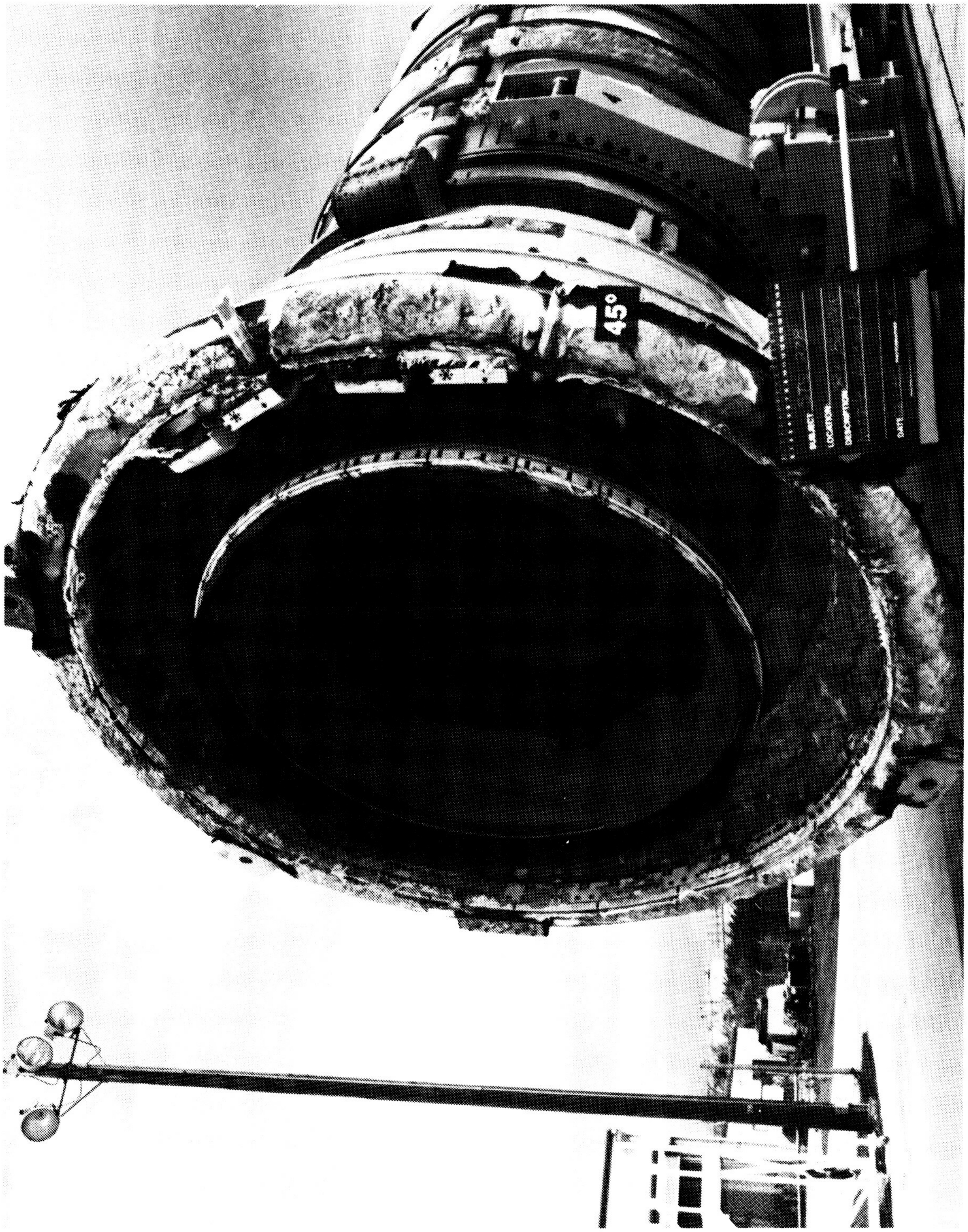

Figure 4.75 STS-27B Aft Exit Cone Fragment

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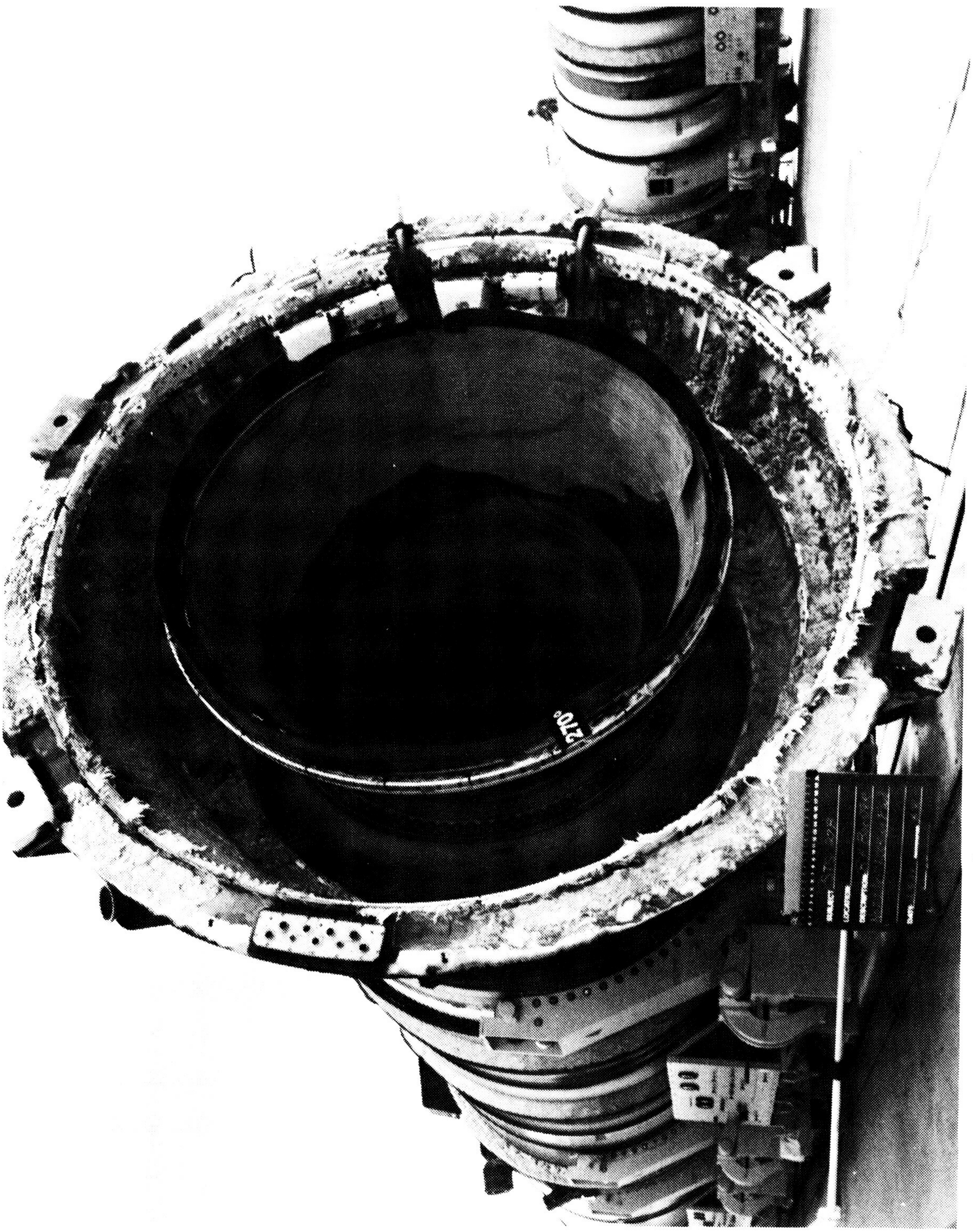

Figure 4.76 STS-27B Aft Exit Cone Fragment

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Figure 4.77 STS-27B Aft Exit Cone EA946 Adhesive Void (250 degrees)

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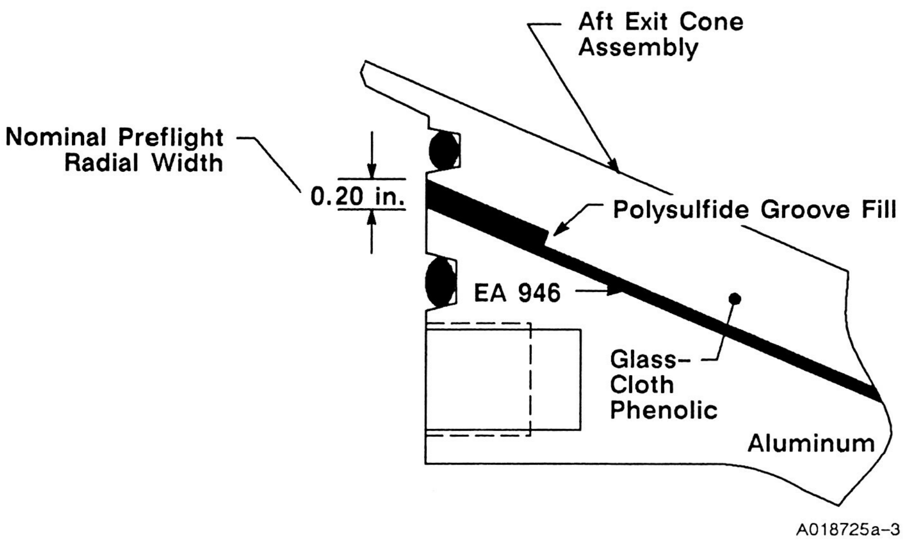
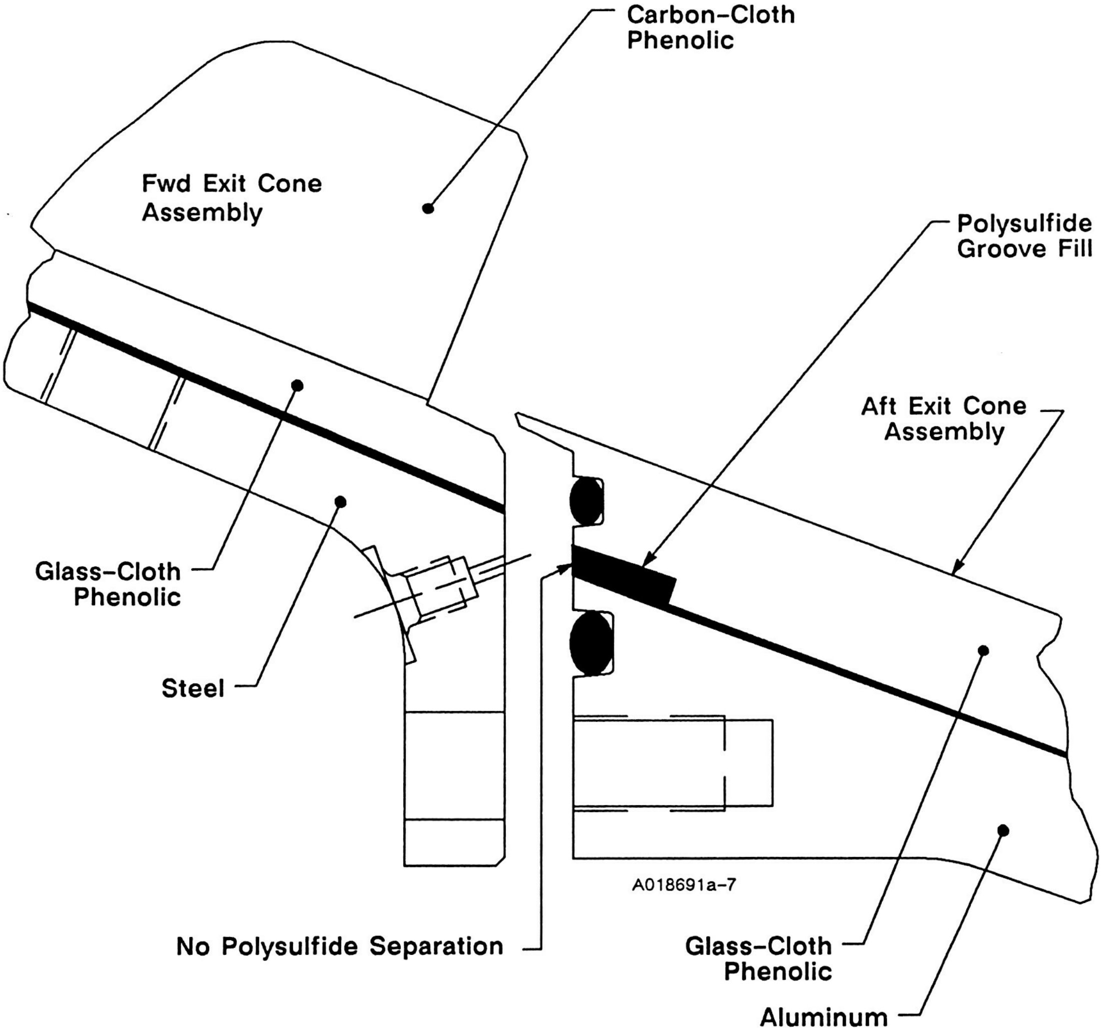
FORM TC 7994-310 (REV 2-88)



Angular Location (deg)	Radial Width (in.)
0	0.16
30	0.17
60	0.17
90	0.16
120	0.16
150	0.17
180	0.17
210	0.17
240	0.20
270	0.16
300	0.17
330	0.17

Figure 4.78 STS-27B Polysulfide Groove Fill Post-Flight Radial Width Measurements



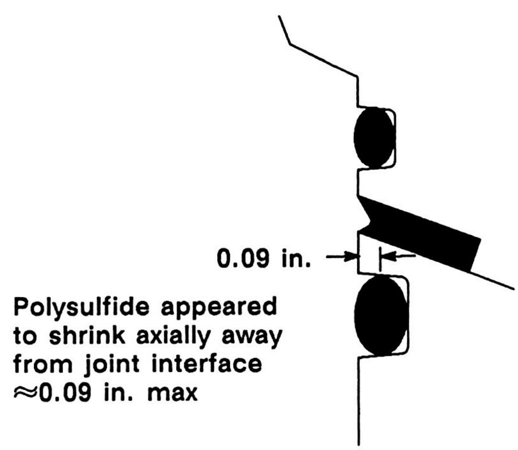
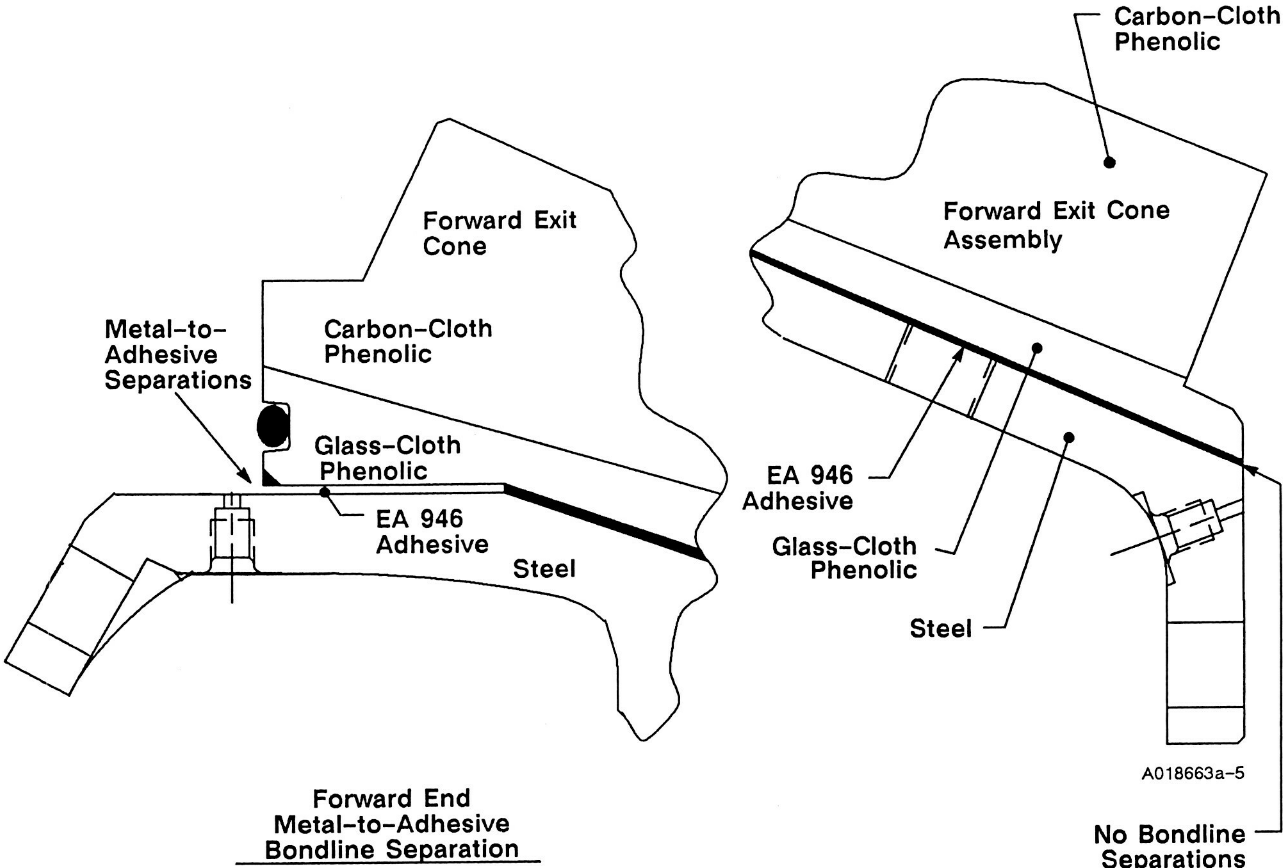


Figure 4.79 STS-27B Polysulfide Condition



Forward End Metal-to-Adhesive Bondline Separation

Location (deg)	Radial Separation (in.)
0	--
15	--
30	0.005
45	--
60	--
75	--
90	--
105	--
120	--
135	--
150	--
165	--
180	--
195	--
210	--
225	--
240	0.005
255	--
270	0.005
285	--
300	0.005
315	--
330	--
345	0.005

Figure 4.80 STS-27B Forward Exit Cone Separations

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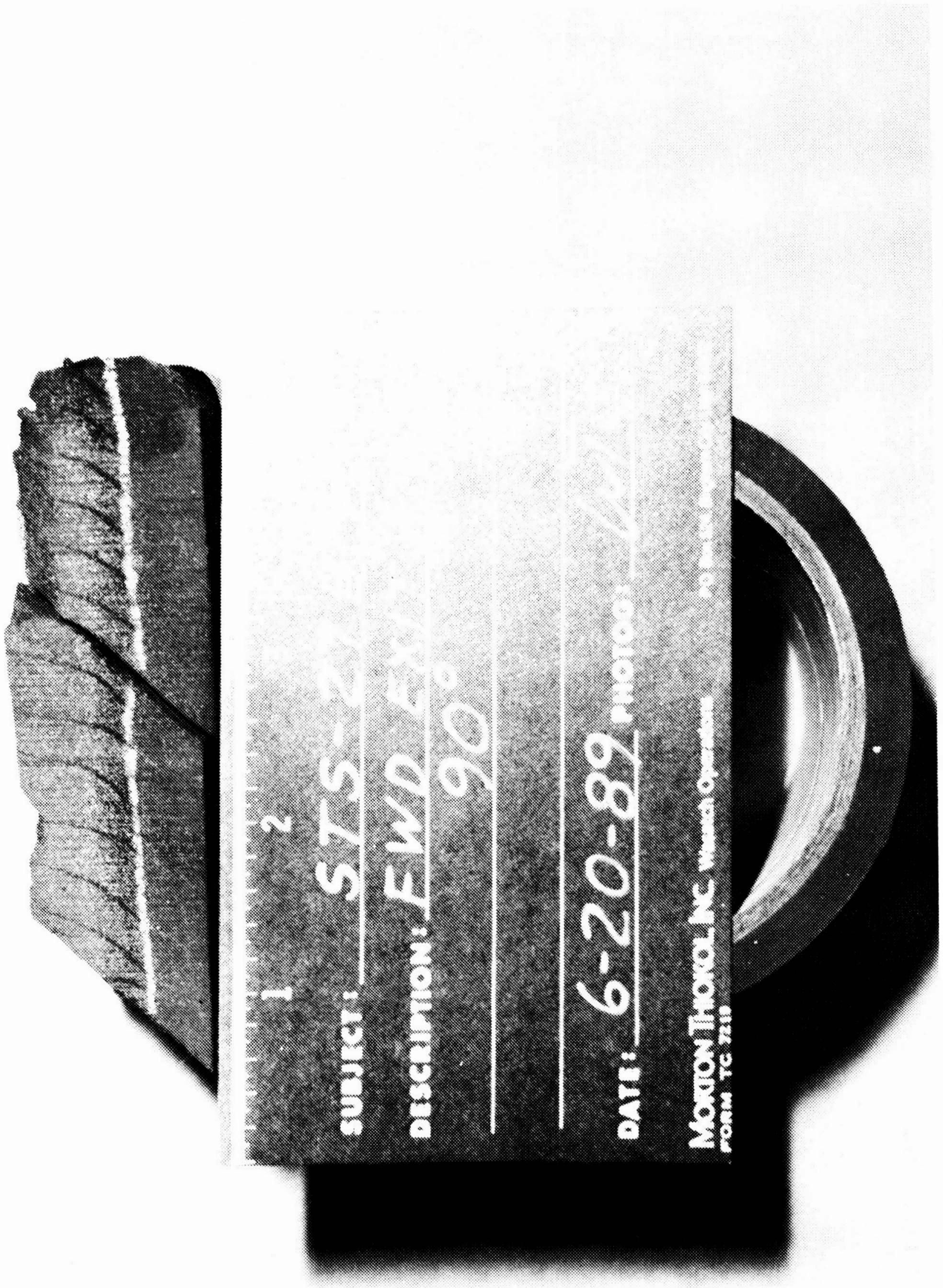

Figure 4.81 STS-27B Forward Exit Cone Liner Section (90 degrees)

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Figure 4.82 STS-27B Forward Exit Cone Liner Section (180 degrees)

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Table 4.7 STS-27B Forward Exit Cone Erosion and Char Data

Angular Location	Stations									
	1	4	8	12	16	20	24	28	32	34
90 degrees*										
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	0.25	0.23
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	0.72	0.69
Adjusted Char**	NA	NA	NA	NA	NA	NA	NA	NA	0.58	0.55
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	1.22	1.15
RSRM Min Liner Thickness	1.808	1.732	1.631	1.526	1.427	1.356	1.322	1.326	1.369	1.405
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	0.12	0.22

* All other degree sections and stations not available due to wedgeout at splashdown
** Measured Char Adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char**}} - 1$$

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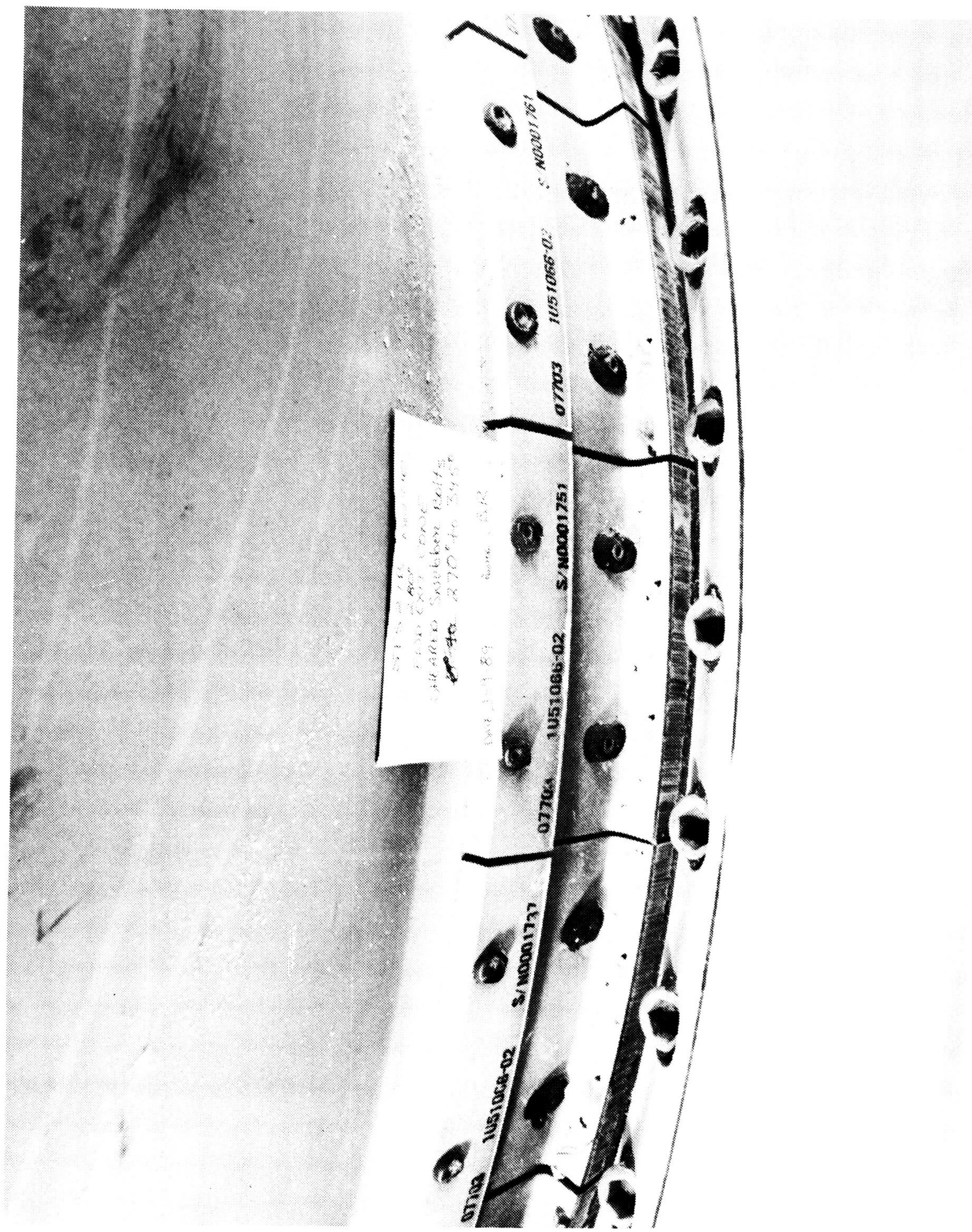

Figure 4.83 STS-27B Snubber Paint Scratches and Sheared Snubber Segment Retainer Bolts (270-345 degrees)

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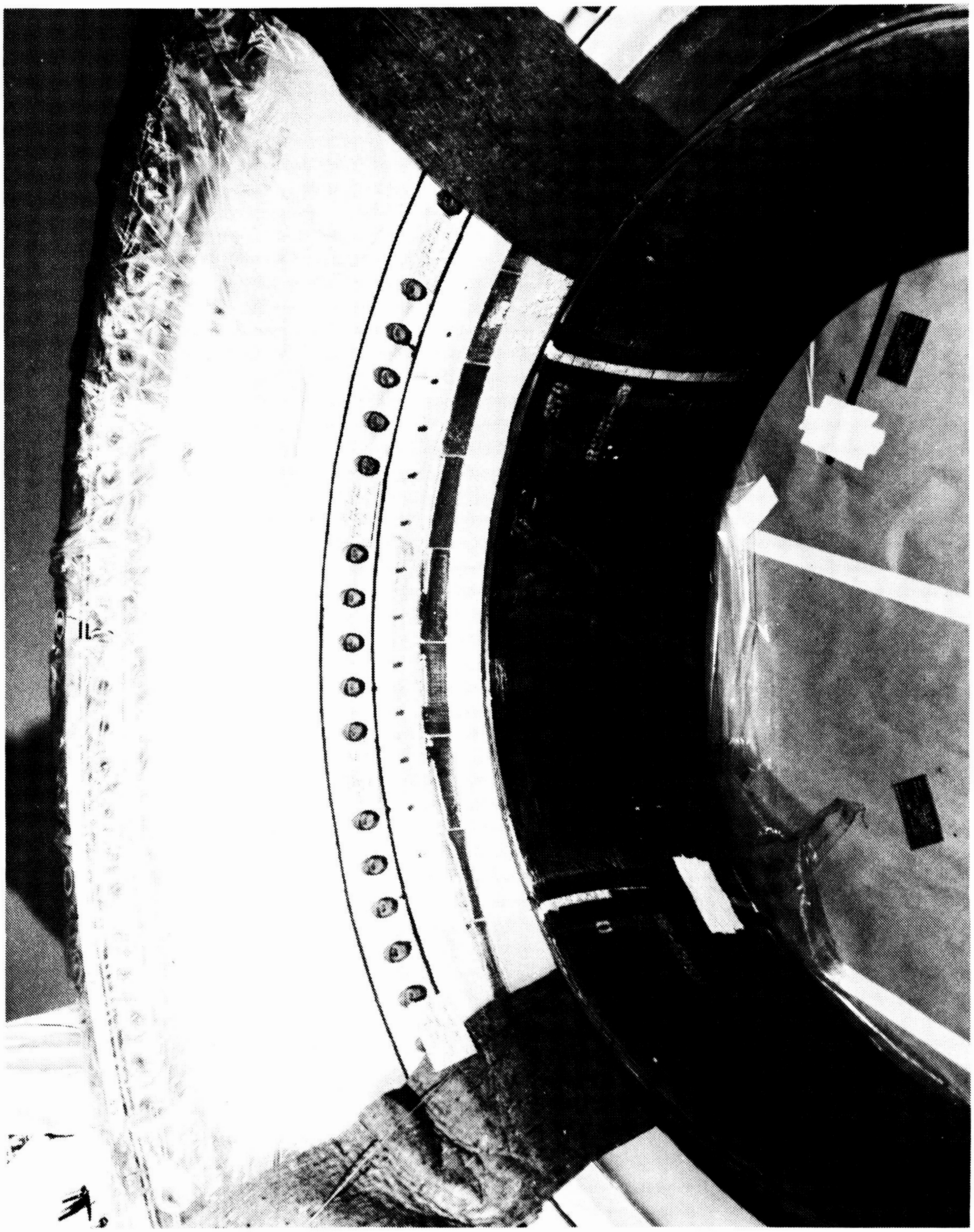

Figure 4.84 STS-27B Bearing Aft End Ring Snubber Impact Scratches
(270-360 degrees)

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Figure 4.85 STS-27B Throat Assembly (0 to 90 degrees)

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Figure 4.86 STS-27B Throat Assembly (90 to 180 degrees)

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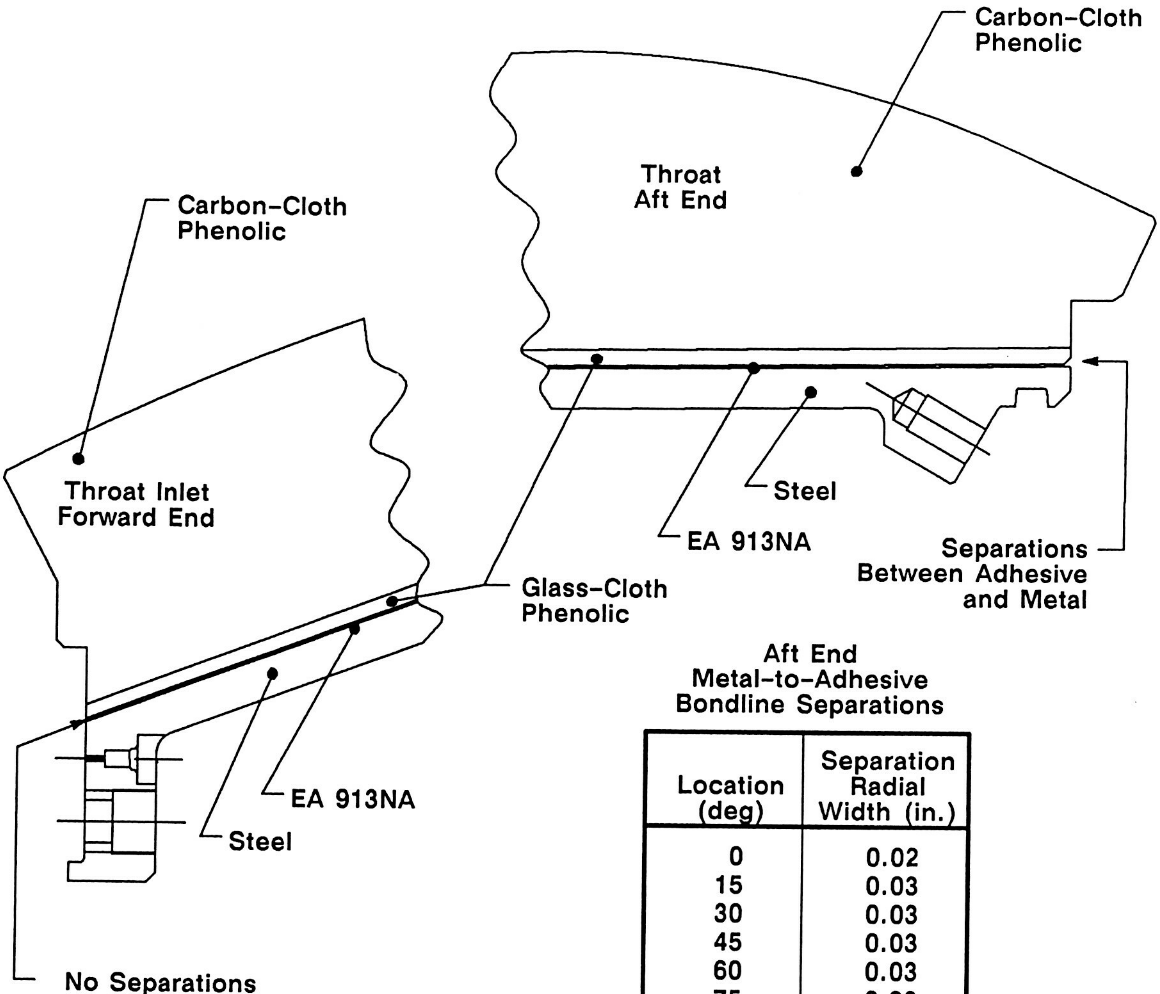

Aft End Metal-to-Adhesive Bondline Separations

Location (deg)	Separation Radial Width (in.)
0	0.02
15	0.03
30	0.03
45	0.03
60	0.03
75	0.03
90	0.02
105	0.02
120	0.02
135	0.03
150	0.02
165	0.02
180	0.02
195	0.02
210	0.02
225	0.02
240	0.02
255	0.02
270	0.02
285	0.02
300	0.02
315	0.02
330	0.03
345	0.03

Figure 4.87 STS-27B Throat Assembly Separations

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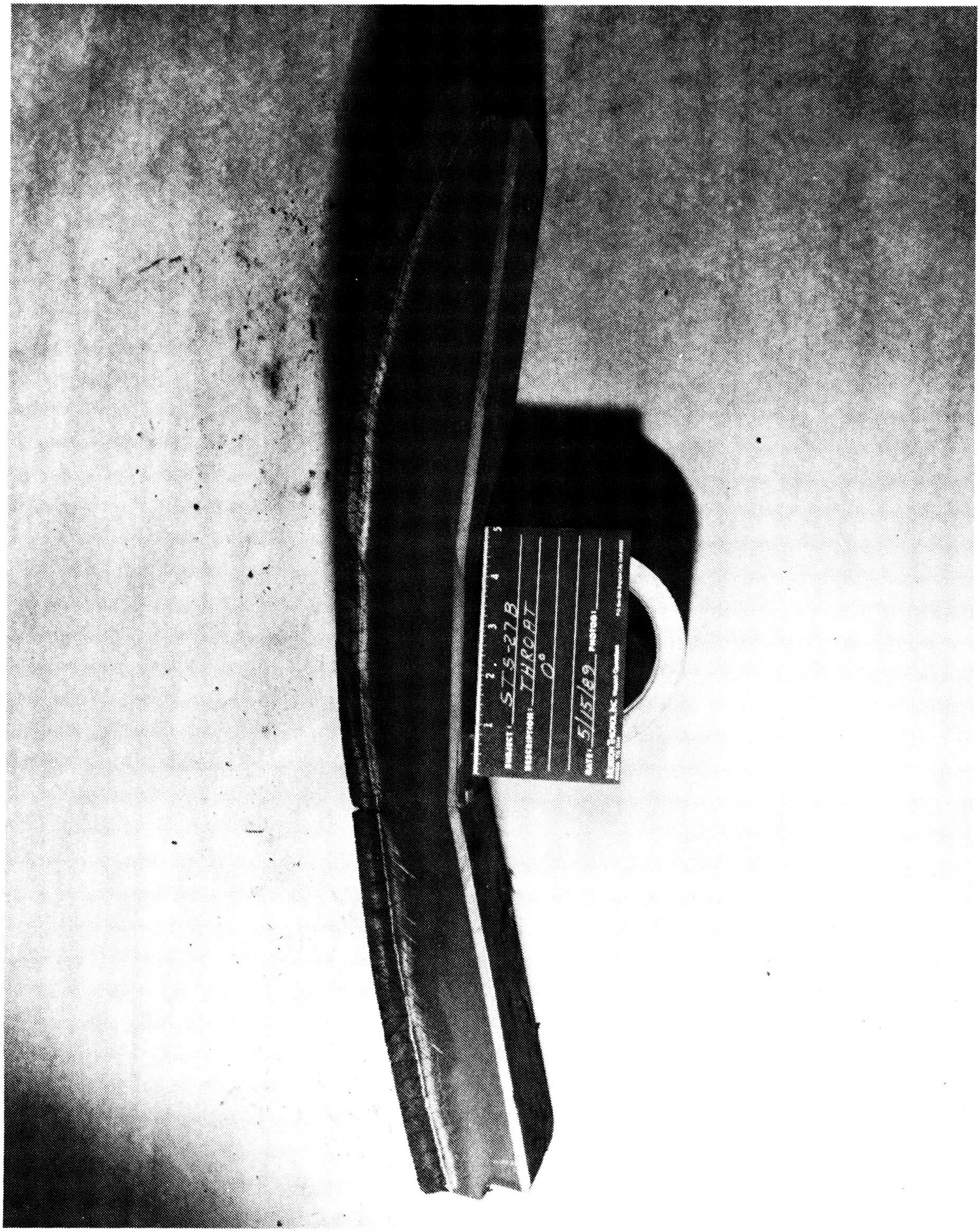

Figure 4.88 STS-27B Throat and Throat Inlet Rings Section (0 degrees)

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Figure 4.89 STS-27B Throat and Throat Inlet Rings Section (180 degrees)

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Table 4.8 STS-27B Throat Assembly Erosion and Char Data

Angular Location	Stations												
0 degrees	1	2	4	6	8	10	12	14	16	18	20	22	23
Measured Erosion	1.07	1.11	1.13	1.16	1.20	1.09	1.11	1.06	1.02	0.89	0.68	0.49	0.37
Measured Char	0.60	0.56	0.63	0.58	0.58	0.52	0.53	0.53	0.56	0.65	0.74	0.83	0.93
Adjusted Char *	0.45	0.42	0.47	0.44	0.44	0.39	0.40	0.40	0.42	0.49	0.56	0.62	0.70
2E + 1.25AC	2.70	2.75	2.85	2.86	2.94	2.67	2.72	2.62	2.57	2.39	2.05	1.76	1.61
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.17	0.18	0.16	0.15	0.08	0.27	0.29	0.39	0.45	0.50	0.57	0.47	0.31
90 degrees													
Measured Erosion	1.03	1.11	1.13	1.15	1.21	1.11	1.09	1.04	1.01	0.88	0.65	0.45	0.35
Measured Char	0.66	0.58	0.66	0.64	0.54	0.53	0.56	0.60	0.63	0.67	0.77	0.82	0.90
Adjusted Char *	0.50	0.44	0.50	0.48	0.41	0.40	0.42	0.45	0.47	0.50	0.58	0.62	0.68
2E + 1.25AC	2.68	2.76	2.88	2.90	2.93	2.72	2.71	2.64	2.61	2.39	2.02	1.67	1.54
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.18	0.17	0.15	0.13	0.09	0.25	0.30	0.37	0.42	0.50	0.60	0.55	0.37
180 degrees													
Measured Erosion	1.13	1.15	1.18	1.22	1.25	1.18	1.13	1.08	1.06	0.92	0.69	0.47	0.40
Measured Char	0.60	0.69	0.66	0.69	0.60	0.57	0.65	0.62	0.59	0.66	0.76	0.90	0.94
Adjusted Char *	0.45	0.52	0.50	0.52	0.45	0.43	0.49	0.47	0.44	0.50	0.57	0.68	0.71
2E + 1.25AC	2.82	2.95	2.98	3.09	3.06	2.89	2.87	2.74	2.67	2.46	2.09	1.78	1.68
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	0.12	0.10	0.11	0.06	0.04	0.17	0.23	0.32	0.39	0.46	0.54	0.45	0.26
270 degrees													
Measured Erosion	NA	1.14	1.15	1.18	1.25	1.12	1.13	1.12	1.06	0.91	0.70	0.48	NA
Measured Char	NA	0.51	0.67	0.62	0.52	0.54	0.55	0.50	0.58	0.59	0.74	0.78	NA
Adjusted Char *	NA	0.38	0.50	0.47	0.39	0.41	0.41	0.38	0.44	0.44	0.56	0.59	NA
2E + 1.25AC	NA	2.76	2.93	2.94	2.99	2.75	2.78	2.71	2.66	2.37	2.09	1.69	NA
RSRM Min Liner Thickness	3.174	3.247	3.314	3.280	3.189	3.397	3.517	3.626	3.710	3.586	3.232	2.583	2.110
Margin of Safety	NA	0.18	0.13	0.12	0.07	0.24	0.27	0.34	0.39	0.51	0.54	0.53	NA

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \text{ X erosion} + 1.25 \text{ X adj char*}} - 1$$

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Figure 4.90 STS-27B -504 Ring Fwd End Post-Burn Wedgeout of Charred CCP (90 degrees)

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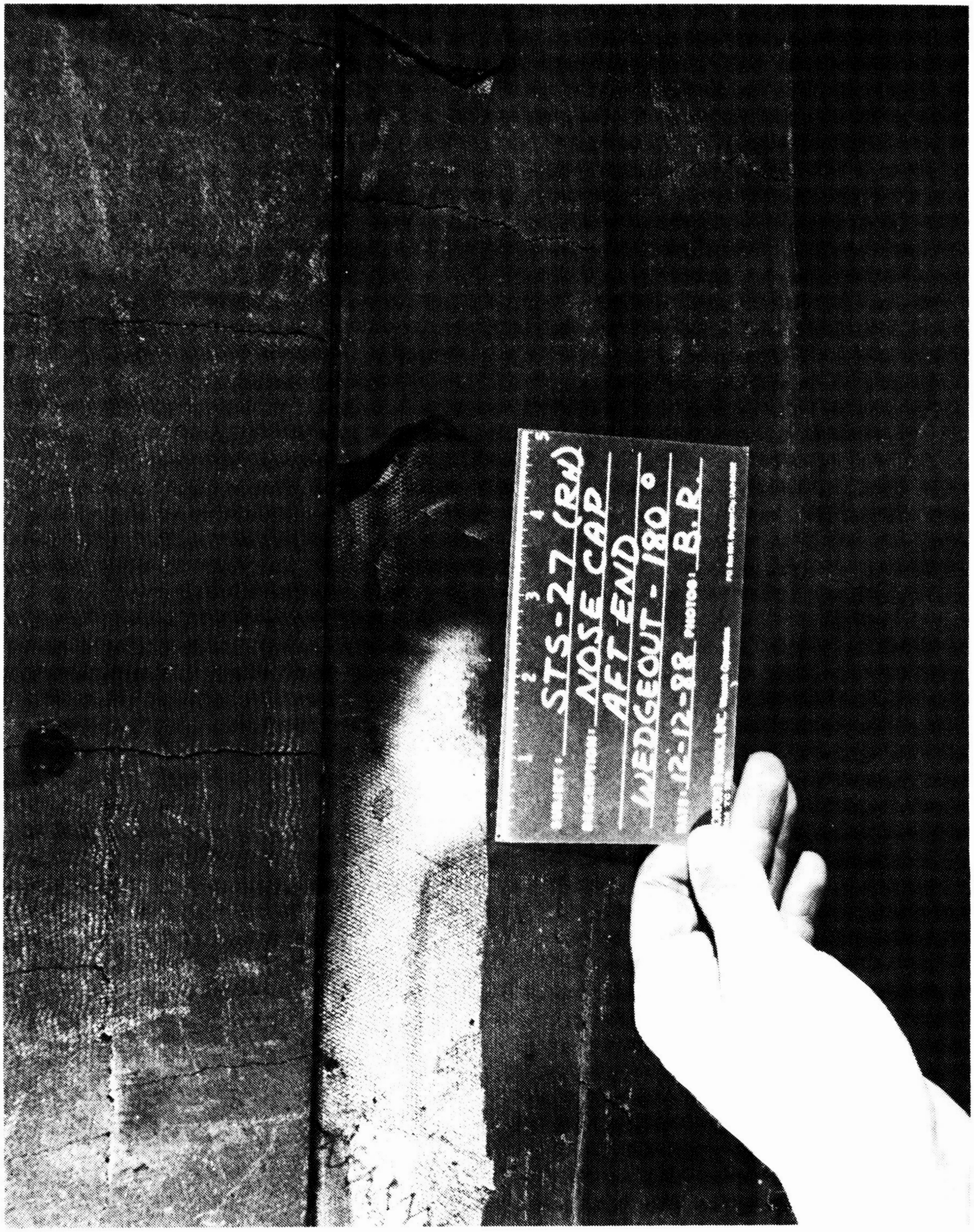

Figure 4.91 STS-27B Nose Cap Aft End Post-Burn Wedgeout of Charred CCP (180 degrees)

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Figure 4.92 STS-27B Nose Cap Sectioned View (180 degrees)

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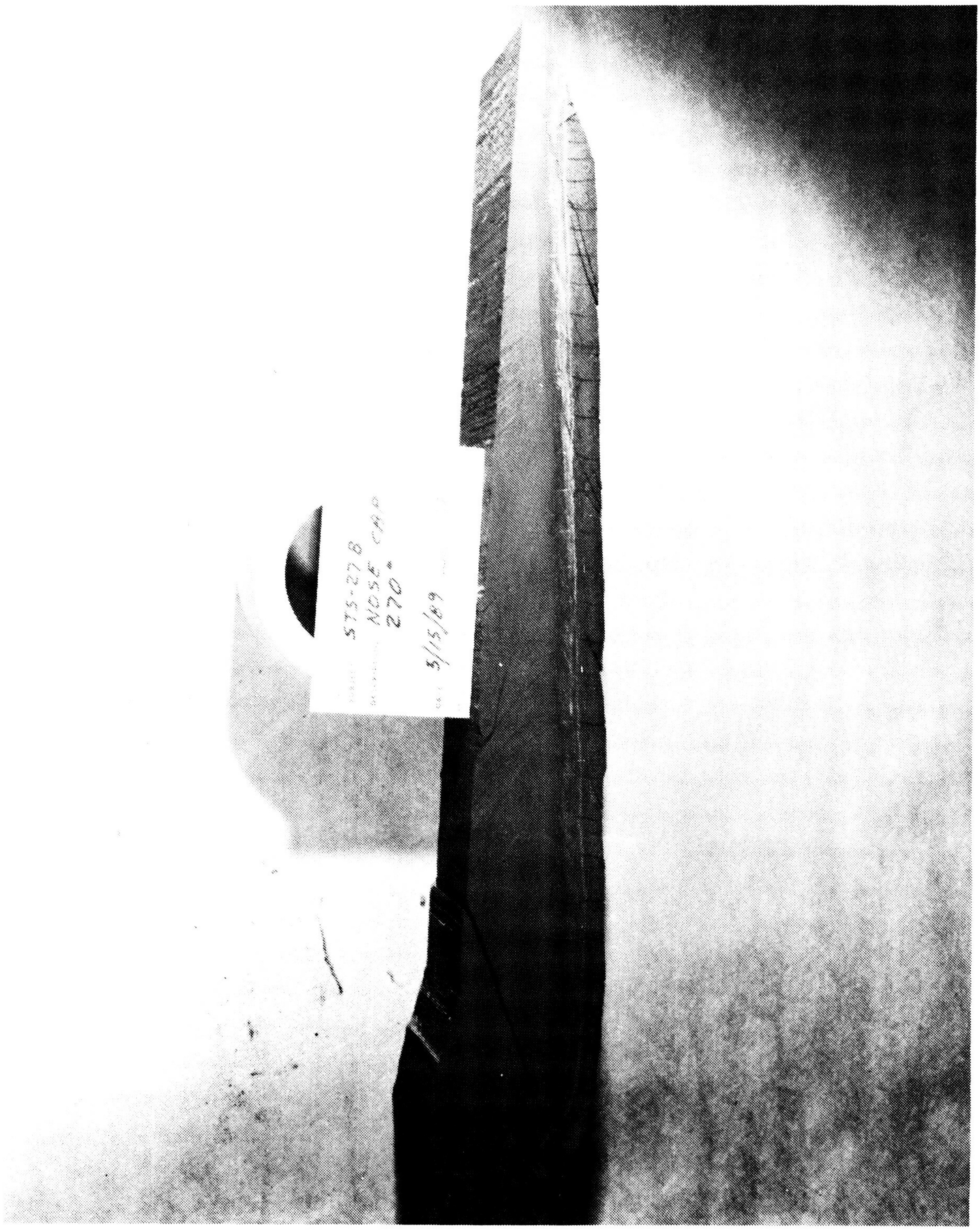

Figure 4.93 STS-27B Nose Cap Sectioned View (270 degrees)

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Figure 4.94 STS-27B -503/-504 Rings Sectioned View (0 degrees)

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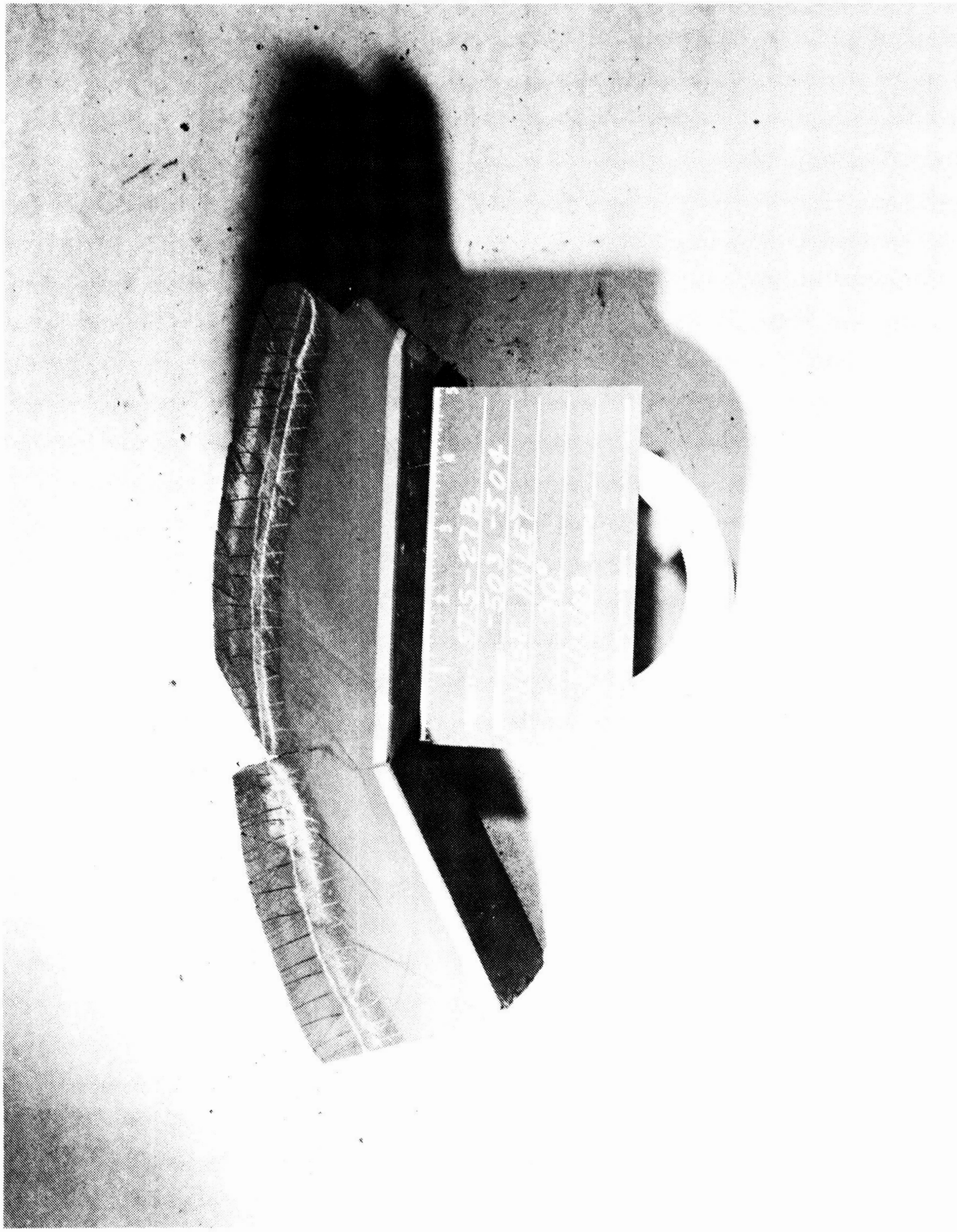

Figure 4.95 STS-27B -503/-504 Rings Sectioned View (90 degrees)

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Table 4.9 STS-27B Nose Inlet Rings (-503, -504) Erosion and Char Data

Angular Location	Stations						
	28	30	32	34	36	38	39
0 degrees							
Measured Erosion	0.98	0.80	0.87	0.79	0.82	0.91	0.94
Measured Char	0.58	0.63	0.62	0.55	0.62	0.63	0.64
Adjusted Char*	0.44	0.47	0.47	0.41	0.47	0.47	0.48
2E + 1.25AC	2.50	2.19	2.32	2.10	2.22	2.41	2.48
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.40	0.48	0.27	0.52	0.44	0.26	0.21
90 degrees							
Measured Erosion	1.07	0.87	0.92	0.83	0.84	0.92	0.95
Measured Char	0.70	0.69	0.60	0.61	0.58	0.62	0.58
Adjusted Char*	0.53	0.52	0.45	0.46	0.44	0.47	0.44
2E + 1.25AC	2.80	2.39	2.40	2.23	2.22	2.42	2.44
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.25	0.36	0.23	0.43	0.44	0.25	0.23
180 degrees							
Measured Erosion	1.14	0.91	0.95	0.86	0.93	0.97	1.02
Measured Char	0.63	0.67	0.76	0.70	0.66	0.67	0.65
Adjusted Char*	0.47	0.50	0.57	0.53	0.50	0.50	0.49
2E + 1.25AC	2.87	2.45	2.61	2.38	2.48	2.57	2.65
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.22	0.33	0.13	0.34	0.29	0.18	0.13
235 degrees							
Measured Erosion	1.12	0.96	0.91	0.83	0.87	0.96	0.99
Measured Char	0.65	0.66	0.72	0.64	0.57	0.56	0.65
Adjusted Char*	0.49	0.50	0.54	0.48	0.43	0.42	0.49
2E + 1.25AC	2.85	2.54	2.50	2.26	2.27	2.45	2.59
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	0.23	0.28	0.18	0.41	0.41	0.24	0.16
315 degrees							
Measured Erosion	NA	0.80	0.87	0.82	0.83	0.96	0.93
Measured Char	NA	0.70	0.65	0.57	0.59	0.55	0.64
Adjusted Char*	NA	0.53	0.49	0.43	0.44	0.41	0.48
2E + 1.25AC	NA	2.26	2.35	2.17	2.21	2.44	2.46
RSRM Min Liner Thkns	3.508	3.252	2.950	3.182	3.200	3.026	3.000
Margin of Safety	NA	0.44	0.26	0.46	0.45	0.24	0.22

* Measured Char Adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

Table 4.10

STS-27B Nose Cap Assembly Erosion and Char Data

Angular Location	Stations 1.5	4	6	8	10	12	14	16	18	20	22	24	26
0 degrees													
Measured Erosion	NA	0.33	0.33	0.39	0.39	0.43	0.57	0.62	0.71	0.91	1.37	NA	NA
Measured Char	NA	0.55	0.45	0.52	0.50	0.55	0.46	0.47	0.40	0.42	0.53	NA	NA
Adjusted Char *	NA	0.44	0.36	0.42	0.40	0.44	0.37	0.38	0.32	0.34	0.42	NA	NA
2E + 1.25AC	NA	1.21	1.11	1.30	1.28	1.41	1.60	1.71	1.82	2.24	3.27	NA	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.68	1.03	0.89	1.08	1.04	0.93	0.93	0.93	0.81	0.44	NA	NA
45 degrees													
Measured Erosion	NA	0.30	0.37	0.37	0.39	0.42	0.45	0.56	0.64	0.83	1.33	NA	NA
Measured Char	NA	0.61	0.55	0.61	0.58	0.53	0.52	0.52	0.51	0.44	0.64	NA	NA
Adjusted Char *	NA	0.49	0.44	0.49	0.46	0.42	0.42	0.42	0.41	0.35	0.51	NA	NA
2E + 1.25AC	NA	1.21	1.29	1.35	1.36	1.37	1.42	1.64	1.79	2.10	3.30	NA	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.68	0.74	0.82	0.96	1.10	1.17	1.01	0.96	0.93	0.43	NA	NA
90 degrees													
Measured Erosion	0.28	0.32	0.35	0.41	0.42	0.44	0.46	0.64	0.71	0.93	1.41	NA	NA
Measured Char	0.60	0.54	0.60	0.59	0.57	0.61	0.63	0.55	0.55	0.55	0.75	NA	NA
Adjusted Char *	0.48	0.43	0.48	0.47	0.46	0.49	0.50	0.44	0.44	0.44	0.60	NA	NA
2E + 1.25AC	1.16	1.18	1.30	1.41	1.41	1.49	1.55	1.83	1.97	2.41	3.57	NA	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	0.53	0.73	0.73	0.74	0.89	0.93	0.99	0.80	0.78	0.68	0.32	NA	NA
135 degrees													
Measured Erosion	0.28	0.35	0.36	0.47	0.46	0.54	0.47	0.73	0.80	1.15	1.71	1.96	NA
Measured Char	0.63	0.61	0.59	0.52	0.55	0.58	0.57	0.48	0.44	0.49	0.67	0.74	NA
Adjusted Char *	0.50	0.49	0.47	0.42	0.44	0.46	0.46	0.38	0.35	0.39	0.54	0.59	NA
2E + 1.25AC	1.19	1.31	1.31	1.46	1.47	1.66	1.51	1.94	2.04	2.79	4.09	4.66	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	0.49	0.56	0.72	0.68	0.81	0.73	1.05	0.70	0.72	0.45	0.15	0.01	NA

* measured char adjusted to end of action time

$$\text{margin of safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char}^*} - 1$$

Table 4.10 (continued)

STS-27B Nose Cap Assembly Erosion and Char Data

Angular Location	Stations 1.5	4	6	8	10	12	14	16	18	20	22	24	26
180 degrees													
Measured Erosion	NA	0.33	0.32	0.48	0.43	0.53	0.60	0.70	0.79	1.03	1.58	NA	NA
Measured Char	NA	0.59	0.60	0.51	0.57	0.54	0.50	0.54	0.52	0.57	0.63	NA	NA
Adjusted Char *	NA	0.47	0.48	0.41	0.46	0.43	0.40	0.43	0.42	0.46	0.50	NA	NA
2E + 1.25AC	NA	1.25	1.24	1.47	1.43	1.60	1.70	1.94	2.10	2.63	3.79	NA	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.63	0.81	0.67	0.87	0.80	0.82	0.70	0.67	0.54	0.24	NA	NA
225 degrees													
Measured Erosion	NA	0.37	0.38	0.48	0.42	0.56	0.61	0.65	0.74	NA	NA	NA	NA
Measured Char	NA	0.52	0.59	0.55	0.53	0.49	0.45	0.45	0.47	NA	NA	NA	NA
Adjusted Char *	NA	0.42	0.47	0.44	0.42	0.39	0.36	0.36	0.38	NA	NA	NA	NA
2E + 1.25AC	NA	1.26	1.35	1.51	1.37	1.61	1.67	1.75	1.95	NA	NA	NA	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.62	0.67	0.63	0.95	0.79	0.85	0.88	0.80	NA	NA	NA	NA
270 degrees													
Measured Erosion	NA	0.32	0.37	0.43	0.47	0.54	0.56	0.69	0.76	1.03	1.54	1.69	1.20
Measured Char	NA	0.63	0.60	0.57	0.55	0.55	0.53	0.43	0.43	0.42	0.56	0.60	0.67
Adjusted Char *	NA	0.50	0.48	0.46	0.44	0.44	0.42	0.34	0.34	0.34	0.45	0.48	0.50
2E + 1.25AC	NA	1.27	1.34	1.43	1.49	1.63	1.65	1.81	1.95	2.48	3.64	3.98	3.03
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.60	0.68	0.72	0.79	0.77	0.87	0.82	0.80	0.64	0.29	0.18	0.28
315 degrees													
Measured Erosion	NA	0.34	0.33	0.37	0.38	0.45	0.52	0.60	0.79	0.99	1.43	1.53	NA
Measured Char	NA	0.51	0.58	0.58	0.51	0.47	0.51	0.48	0.44	0.41	0.55	0.63	NA
Adjusted Char *	NA	0.41	0.46	0.46	0.41	0.38	0.41	0.38	0.35	0.33	0.44	0.50	NA
2E + 1.25AC	NA	1.19	1.24	1.32	1.27	1.37	1.55	1.68	2.02	2.39	3.41	3.69	NA
RSRM Min Liner Thickness	1.776	2.038	2.248	2.458	2.668	2.878	3.088	3.298	3.507	4.055	4.713	4.691	3.863
Margin of Safety	NA	0.71	0.81	0.86	1.10	1.10	0.99	0.96	0.74	0.70	0.38	0.27	NA

* measured char adjusted to end of action time

$$\text{margin of safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

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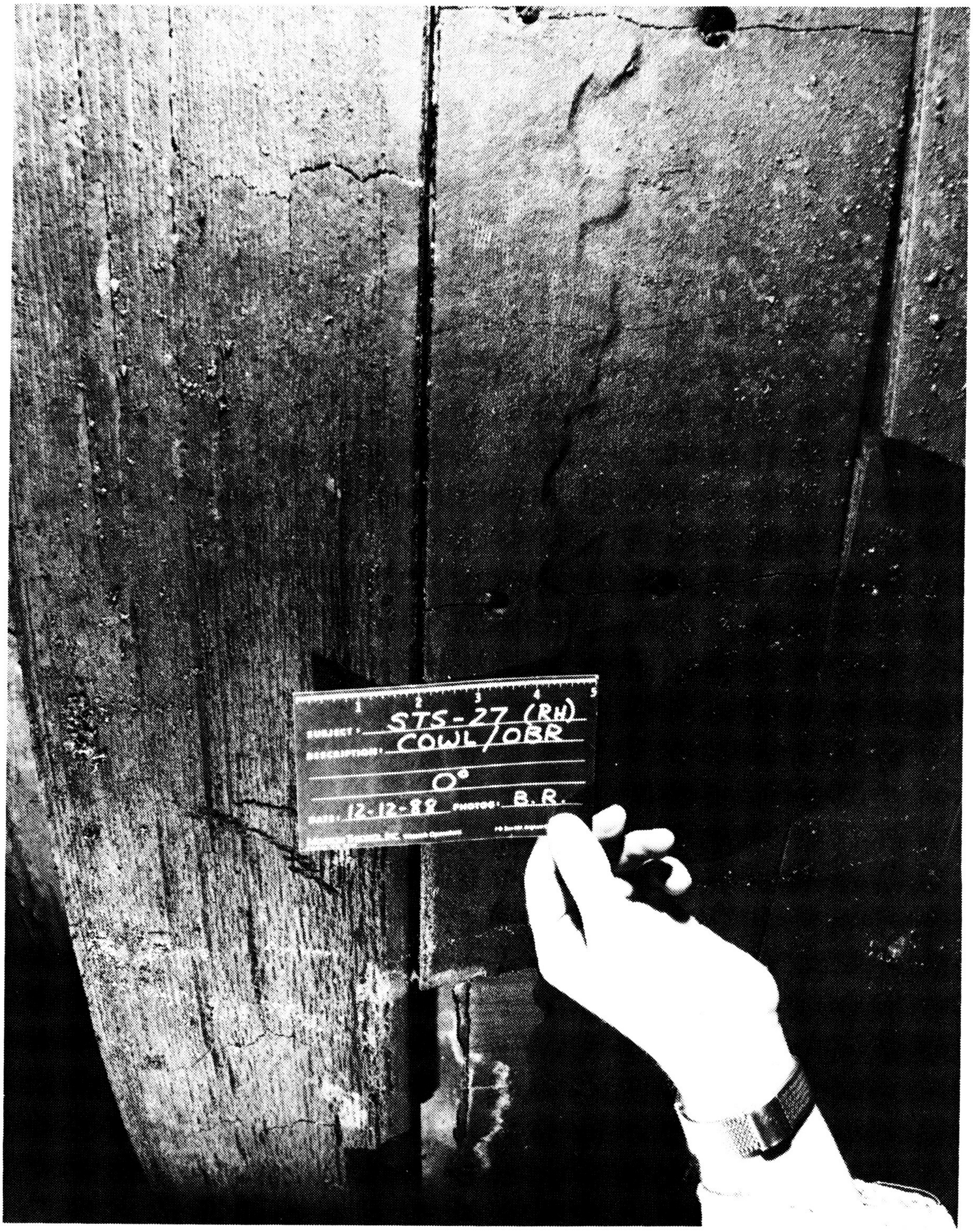

Figure 4.96 STS-27B Cowl/OBR Closeup View (0 degrees)

Figure 4.97 STS-27B Cowl/OBR Closeup View (180 degrees)

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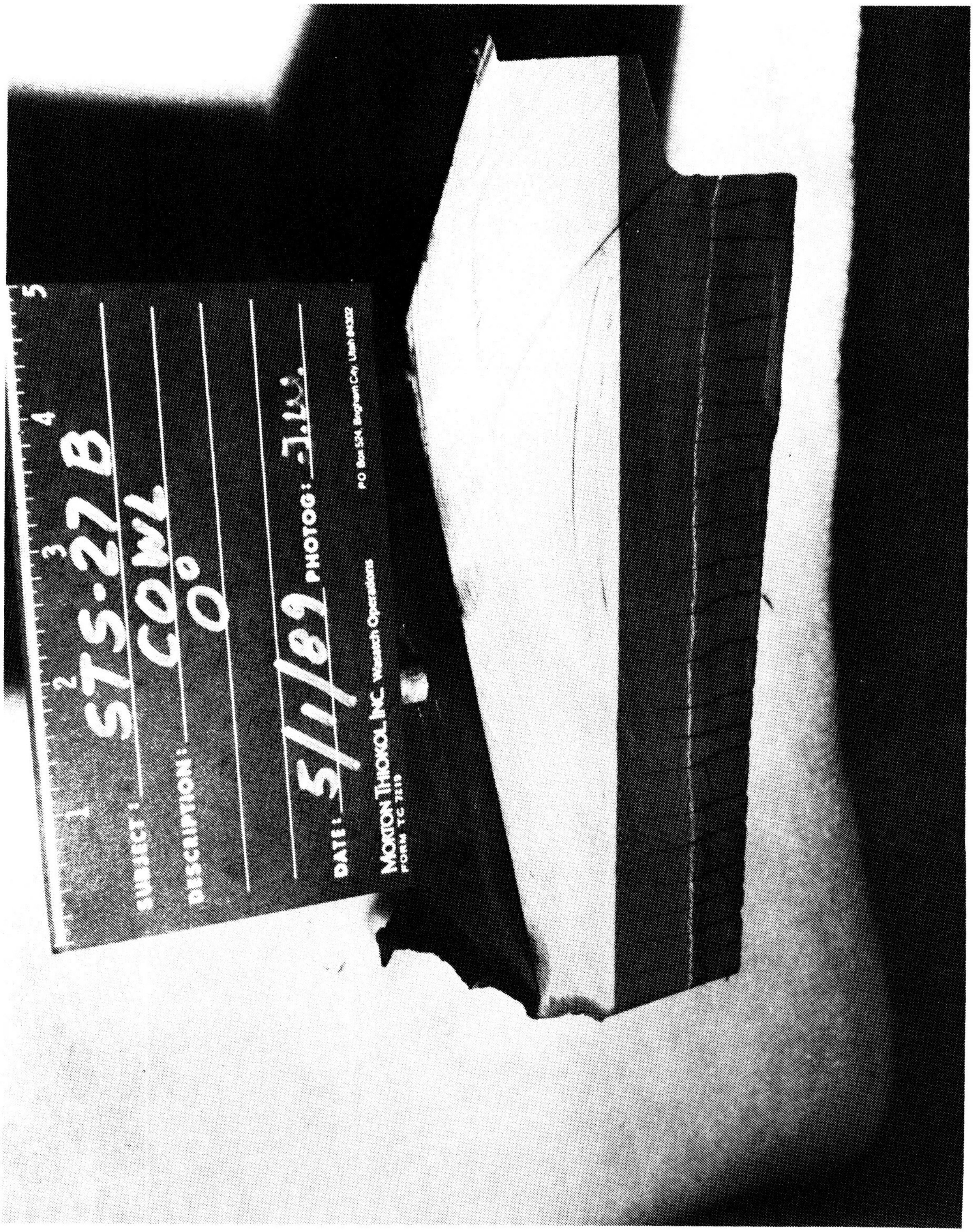

Figure 4.98 STS-27B Cowl Ring Sectioned View (0 degrees)

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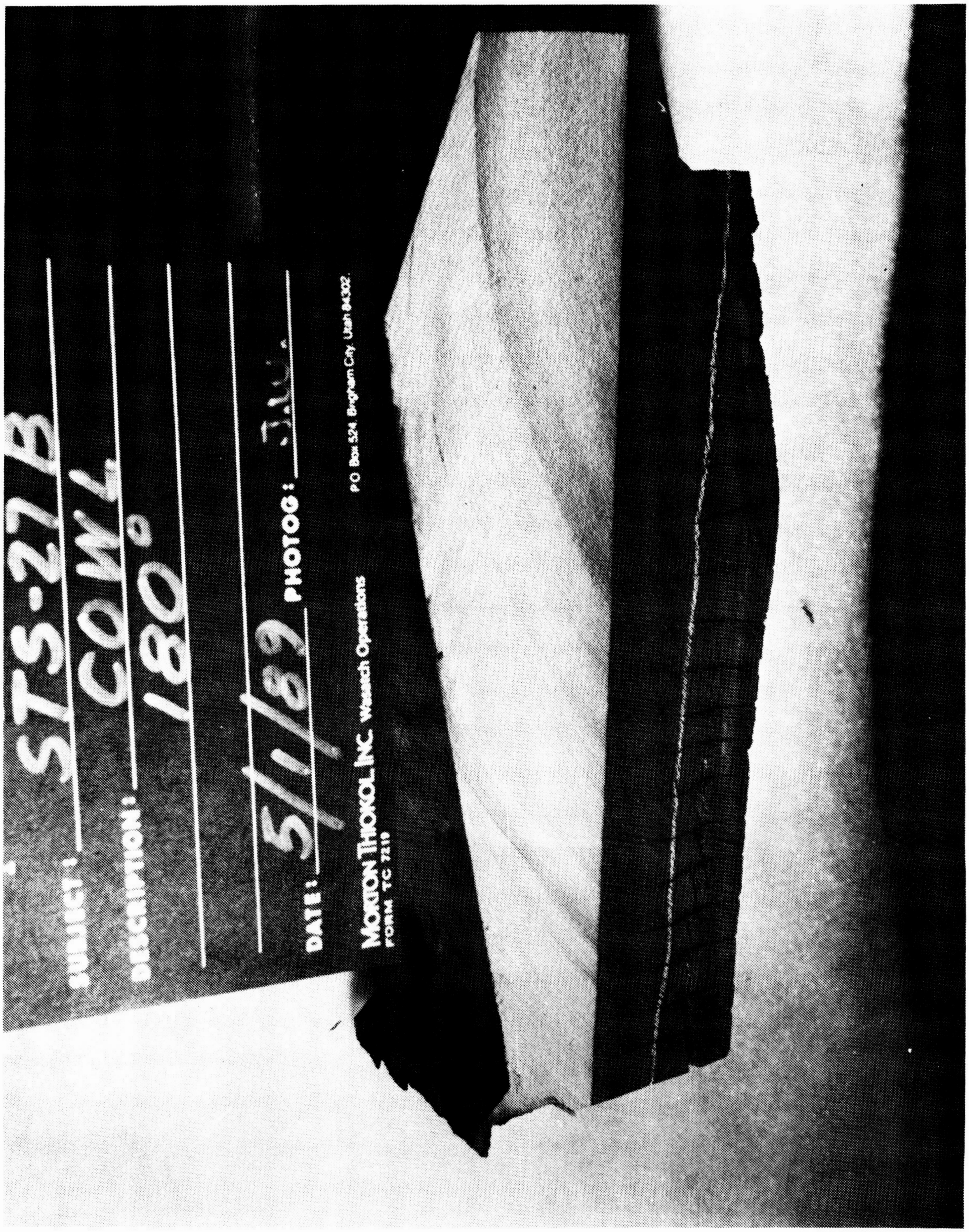

Figure 4.99 STS-27B Cowl Ring Sectioned View (180 degrees)

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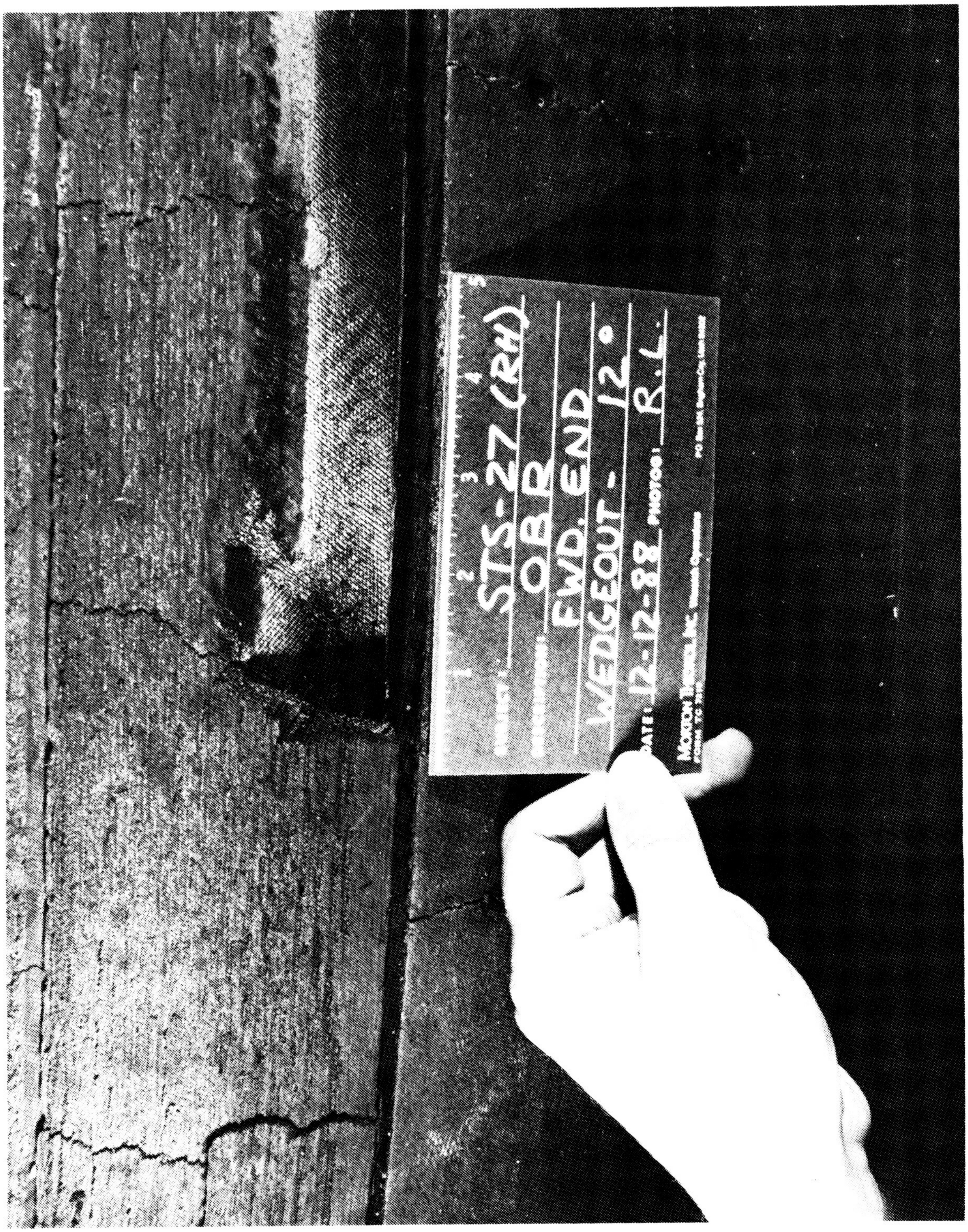

Figure 4.100 STS-27B OBR Fwd End Post-Burn Wedgeout of Charred CCP (12 degrees)

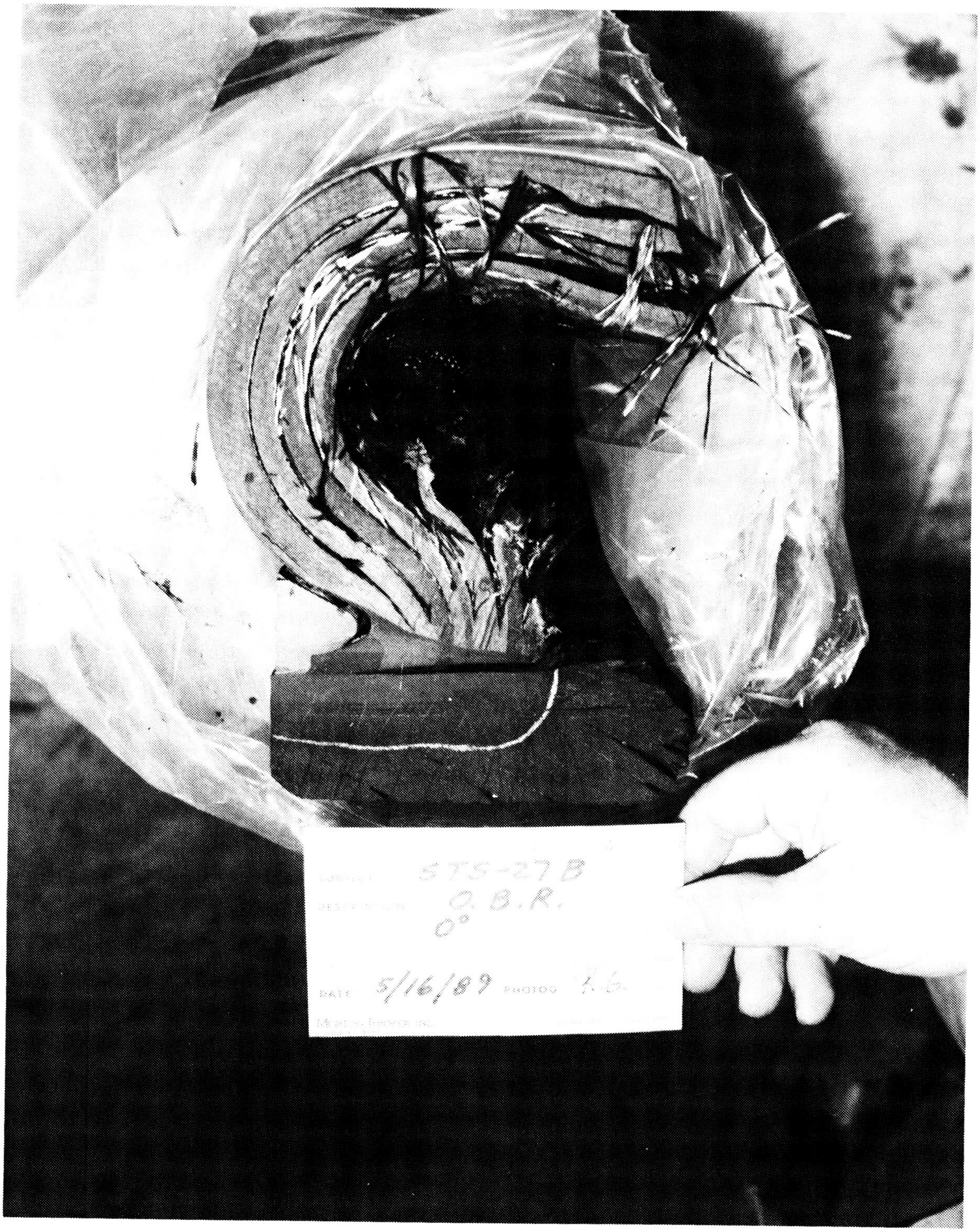

Figure 4.101 STS-27B OBR/Flex Boot Section (0 degrees)

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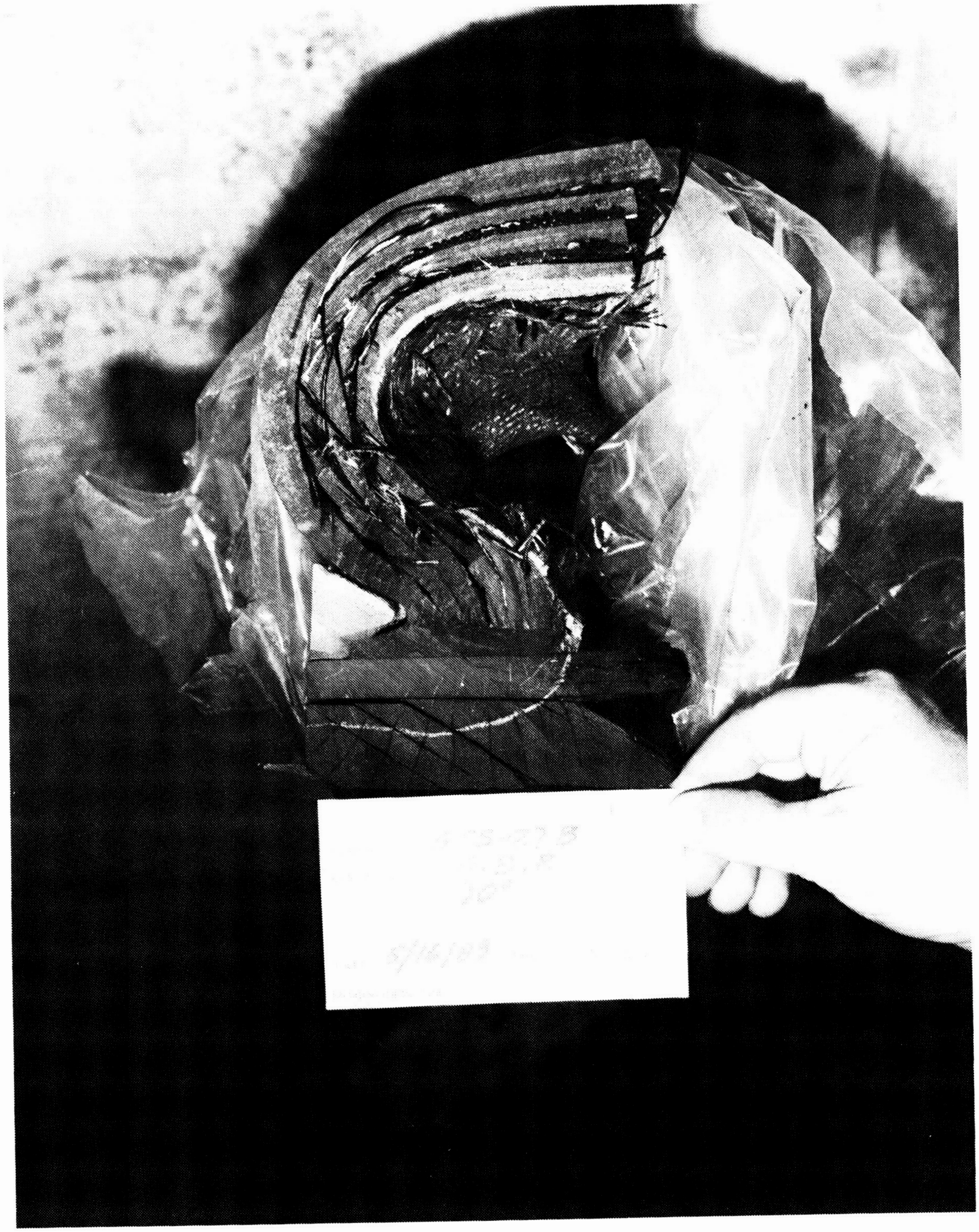

Figure 4.102 STS-27B OBR/Flex Boot Section (90 degrees)

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Figure 4.103 STS-27B OBR/Flex Boot Section (180 degrees)

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Figure 4.104 STS-27B OBR/Flex Boot Section (270 degrees)

Table 4.11

STS-27B Cowl/OBR Erosion and Char Data

Angular Location	Stations												
0 degrees	0	1	2	3	4	5	6	7	8	9	10	11	12
Measured Erosion	0.17	0.21	0.26	0.27	0.28	0.19	0.17	0.13	NA	0.04	0.01	0.01	0.02
Measured Char	0.53	0.56	0.63	0.67	0.75	0.84	0.83	0.84	NA	0.75	0.72	0.70	1.02
Adjusted char *	0.42	0.45	0.50	0.54	0.60	0.67	0.66	0.67	NA	0.60	0.58	0.56	0.82
2E + 1.25AC	0.87	0.98	1.15	1.21	1.31	1.22	1.17	1.10	NA	0.83	0.74	0.72	1.06
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.63	0.53	0.37	0.37	0.32	0.48	0.61	0.79	NA	1.02	1.28	1.36	0.62
40 degrees													
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.05	0.01	0.00	0.00
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.85	0.84	0.83	1.34
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.68	0.67	0.66	1.07
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.95	0.86	0.83	1.34
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.76	0.96	1.05	0.28
45 degrees													
Measured Erosion	0.15	0.18	0.21	0.24	0.18	NA	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.63	0.69	0.73	0.78	0.83	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.50	0.55	0.58	0.62	0.66	NA	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	0.93	1.05	1.15	1.26	1.19	NA	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.53	0.43	0.37	0.31	0.46	NA	NA	NA	NA	NA	NA	NA	NA
90 degrees													
Measured Erosion	0.16	0.21	0.24	0.27	0.25	NA	NA	NA	NA	0.05	0.05	0.02	0.01
Measured Char	0.70	0.69	0.68	0.77	0.83	NA	NA	NA	NA	0.87	0.85	0.86	1.21
Adjusted char *	0.56	0.55	0.54	0.62	0.66	NA	NA	NA	NA	0.70	0.68	0.69	0.97
2E + 1.25AC	1.02	1.11	1.16	1.31	1.33	NA	NA	NA	NA	0.97	0.95	0.90	1.23
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.39	0.35	0.36	0.26	0.30	NA	NA	NA	NA	0.73	0.78	0.89	0.39
135 degrees													
Measured Erosion	0.16	0.23	0.28	0.30	0.32	NA	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.65	0.65	0.69	0.70	0.71	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.52	0.52	0.55	0.56	0.57	NA	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	0.97	1.11	1.25	1.30	1.35	NA	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.46	0.35	0.26	0.27	0.28	NA	NA	NA	NA	NA	NA	NA	NA

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char}^*} - 1$$

Table 4.11 (continued)
STS-27B Cowl/OBR Erosion and Char Data

Angular Location	Stations												
140 degrees	0	1	2	3	4	5	6	7	8	9	10	11	12
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.82	0.68	0.76	1.38
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.66	0.54	0.61	1.10
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.82	0.68	0.76	1.38
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.04	1.48	1.24	0.24
180 degrees													
Measured Erosion	0.21	0.25	0.29	0.30	0.27	NA	NA	NA	NA	0.00	0.00	0.00	0.00
Measured Char	0.70	0.63	0.66	0.71	0.75	NA	NA	NA	NA	0.85	0.83	0.87	1.36
Adjusted char *	0.56	0.50	0.53	0.57	0.60	NA	NA	NA	NA	0.68	0.66	0.70	1.09
2E + 1.25AC	1.12	1.13	1.24	1.31	1.29	NA	NA	NA	NA	0.85	0.83	0.87	1.36
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.27	0.33	0.27	0.26	0.34	NA	NA	NA	NA	0.97	1.03	0.95	0.26
220 degrees													
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	0.00	0.01
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.76	0.78	1.12
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.61	0.62	0.90
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.76	0.78	1.14
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.22	1.18	0.50
225 degrees													
Measured Erosion	0.16	0.24	0.26	0.30	0.30	NA	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.68	0.61	0.60	0.61	0.68	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.54	0.49	0.48	0.49	0.54	NA	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	1.00	1.09	1.12	1.21	1.28	NA	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.42	0.38	0.41	0.37	0.35	NA	NA	NA	NA	NA	NA	NA	NA
270 degrees													
Measured Erosion	0.19	0.23	0.26	0.27	0.24	NA	NA	NA	NA	0.03	0.01	0.00	0.00
Measured Char	0.59	0.60	0.59	0.63	0.71	NA	NA	NA	NA	0.89	0.84	0.87	1.22
Adjusted char *	0.47	0.48	0.47	0.50	0.57	NA	NA	NA	NA	0.71	0.67	0.70	0.98
2E + 1.25AC	0.97	1.06	1.11	1.17	1.19	NA	NA	NA	NA	0.95	0.86	0.87	1.22
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.46	0.41	0.42	0.41	0.46	NA	NA	NA	NA	0.76	0.96	0.95	0.40

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{erosion} + 1.25 \times \text{adj char*}} - 1$$

Table 4.11 (continued)
STS-27B Cowl/OBR Erosion and Char Data

Angular Location	Stations												
315 degrees	0	1	2	3	4	5	6	7	8	9	10	11	12
Measured Erosion	0.18	0.23	0.26	0.28	0.28	NA	NA	NA	NA	NA	NA	NA	NA
Measured Char	0.62	0.62	0.65	0.68	0.69	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted char *	0.50	0.50	0.52	0.54	0.55	NA	NA	NA	NA	NA	NA	NA	NA
2E + 1.25AC	0.98	1.08	1.17	1.24	1.25	NA	NA	NA	NA	NA	NA	NA	NA
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	0.45	0.39	0.35	0.33	0.39	NA	NA	NA	NA	NA	NA	NA	NA
320 degrees													
Measured Erosion	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	0.01	0.01	0.00
Measured Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.72	0.73	0.80	1.02
Adjusted char *	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.58	0.58	0.64	0.82
2E + 1.25AC	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.74	0.75	0.82	1.02
RSRM Min Liner Thickness	1.421	1.499	1.577	1.655	1.733	1.811	1.889	1.967	1.597	1.675	1.687	1.700	1.712
Margin of Safety	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.26	1.25	1.07	0.68

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \text{ X erosion} + 1.25 \text{ X adj char*}} - 1$$

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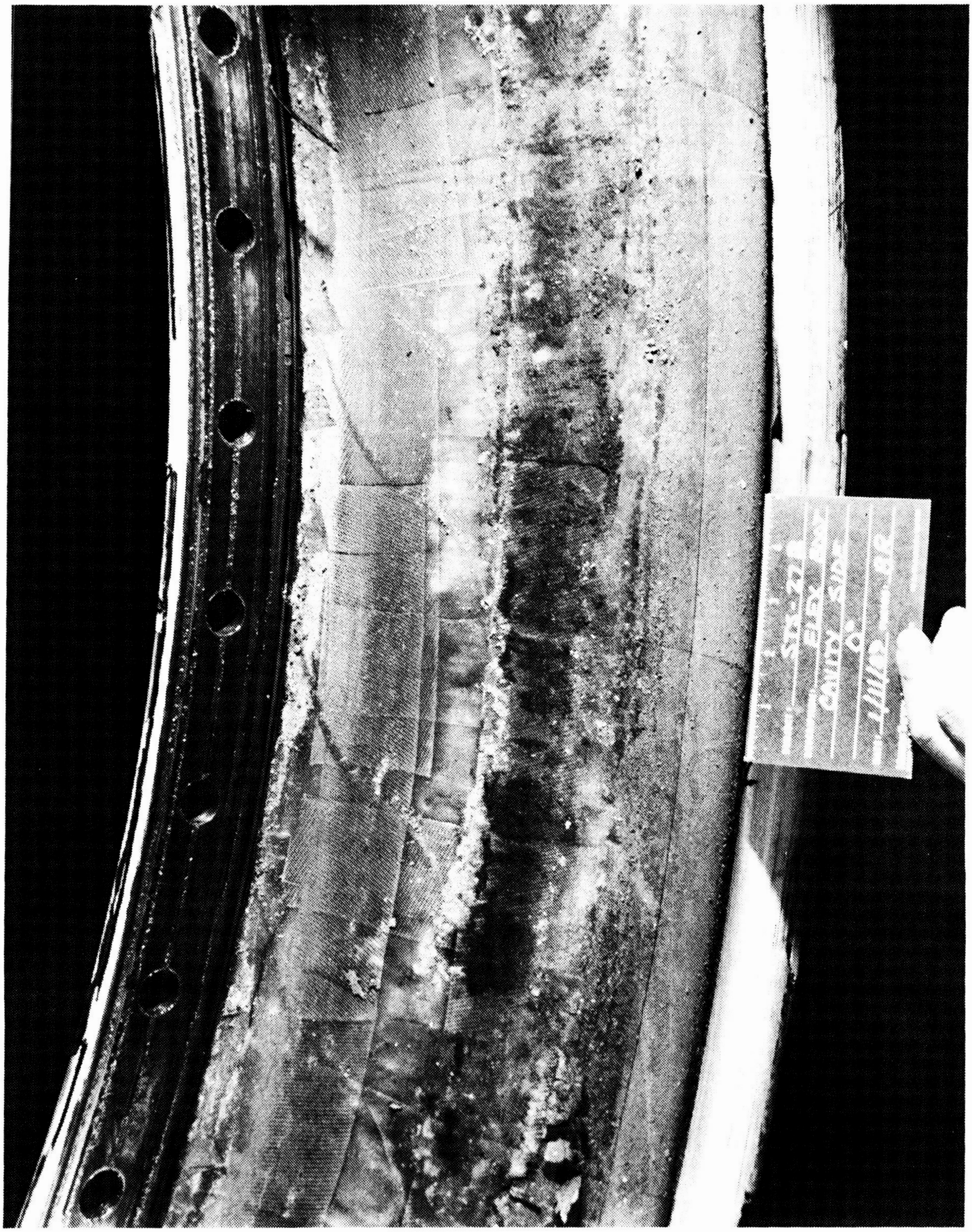
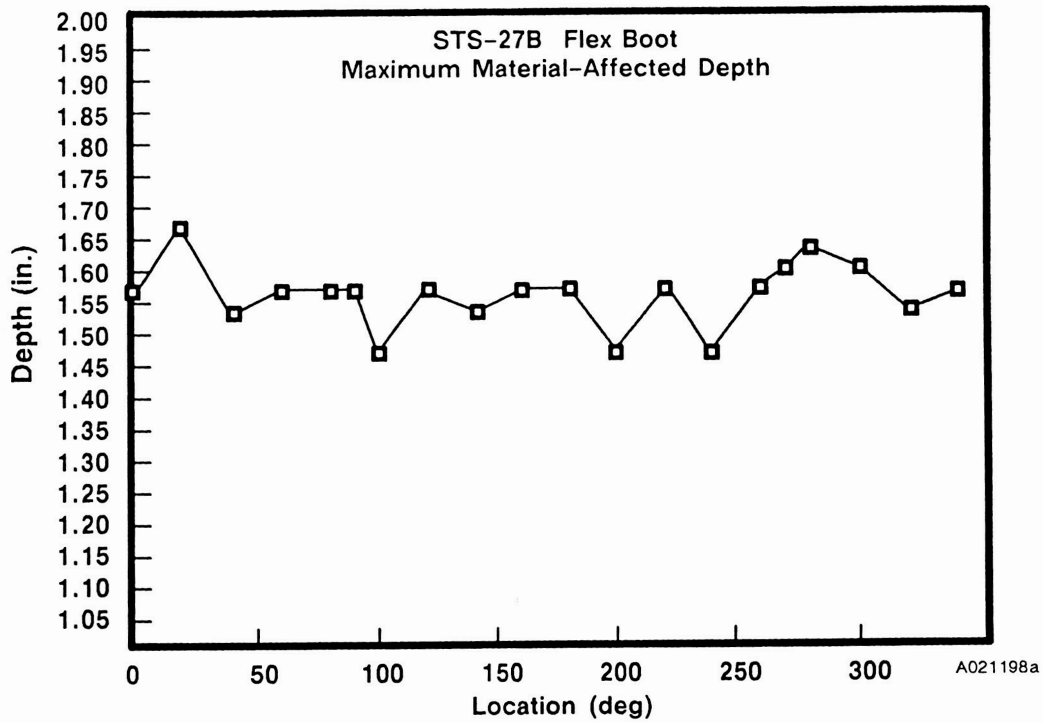


Figure 4.105 STS-27B Flex Boot Cavity Side (0 degrees)



Location (deg)	Remaining Plies	Maximum Material-Affected Depth	Performance Margin of Safety
0	4.0	1.08	0.54
40	3.9	1.11	0.50
90	3.7	1.17	0.42
140	3.4	1.27	0.31
180	3.9	1.11	0.50
220	3.8	1.14	0.46
270	3.0	1.40	0.19
320	3.6	1.20	0.39

$$\text{PMS} = \frac{\text{Minimum Design Thickness}}{1.5\ (\text{Maximum Material-Affected Depth})} - 1$$

Figure 4.106 STS-27B Flex Boot Performance

Figure 4.107 STS-27B Fixed Housing Insulation Fwd End Post-Burn Wedgeout of Charred CCP (200 degrees)

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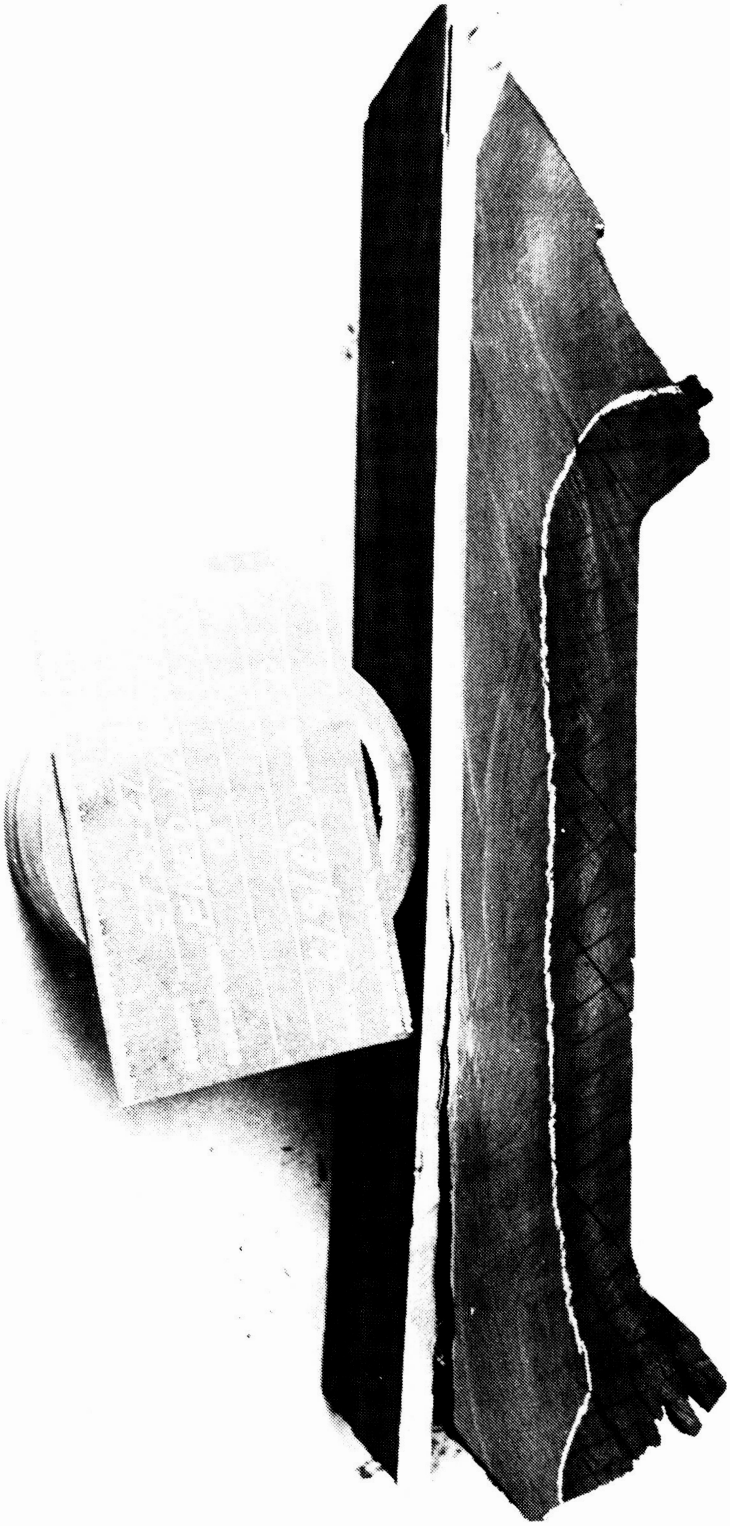

Figure 4.108 STS-27B Fixed Housing Insulation Sectioned View
(0 degrees)

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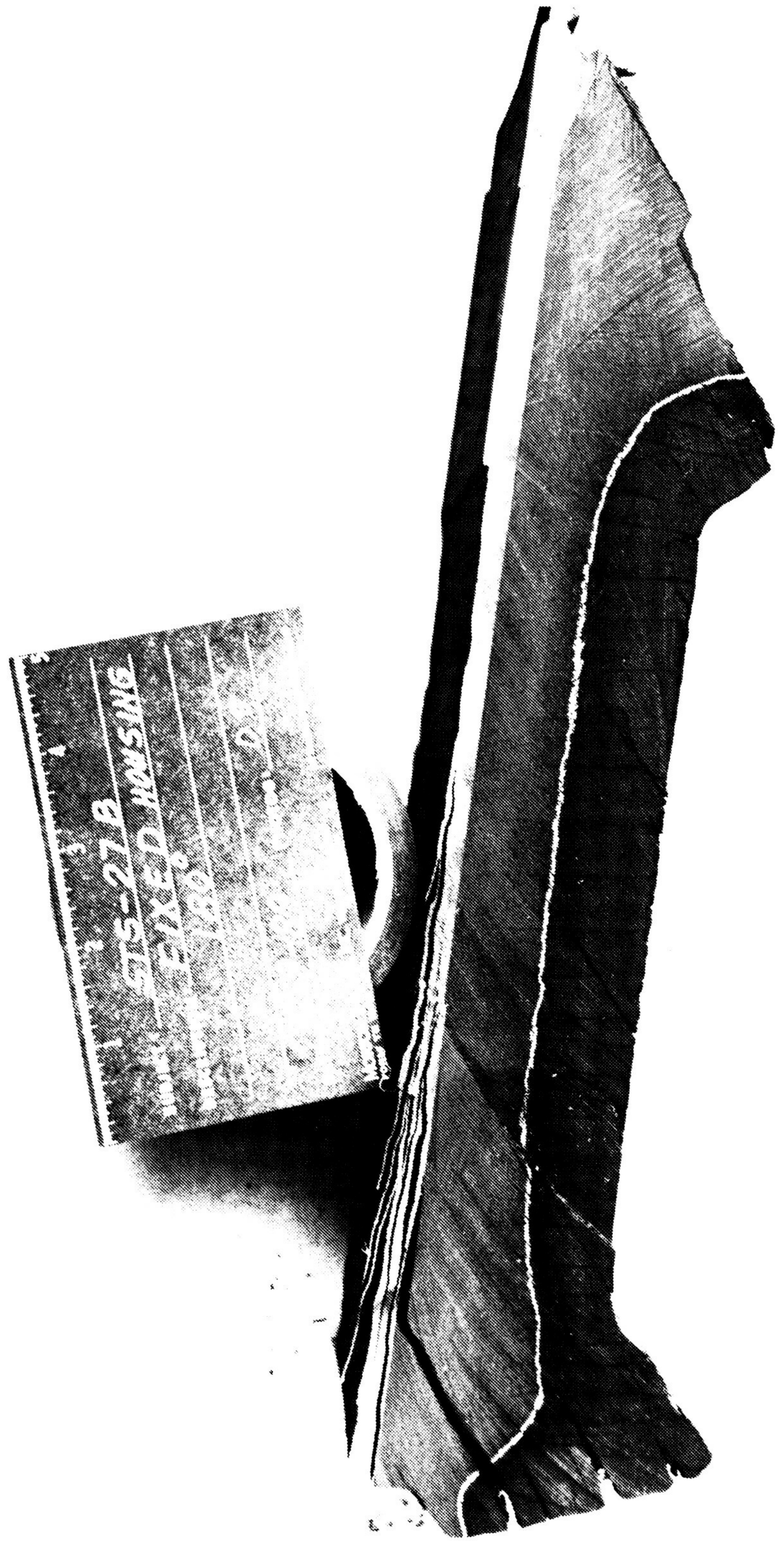

Figure 4.109 STS-27B Fixed Housing Insulation Sectioned View (180 degrees)

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Table 4.12
STS-27B Fixed Housing Insulation Erosion and Char Data

Angular Location	Stations 0	1	2	3	4	5	6	7	8	9	11
0 degrees											
Measured Erosion	0.07	0.07	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.10
Measured Char	0.93	1.03	1.07	1.03	0.94	0.95	0.92	0.83	0.80	0.87	1.60
Adjusted Char*	0.74	0.82	0.86	0.82	0.75	0.76	0.74	0.66	0.64	0.70	1.28
2E + 1.25AC	1.07	1.17	1.07	1.05	0.94	0.95	0.92	0.85	0.80	0.87	1.80
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.56	0.78	0.71	0.74	0.95	0.93	0.99	1.16	1.30	1.79	0.69
90 degrees											
Measured Erosion	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Measured Char	1.25	1.21	1.17	1.16	1.10	1.09	1.09	1.00	0.90	0.88	1.87
Adjusted Char*	1.00	0.97	0.94	0.93	0.88	0.87	0.87	0.80	0.72	0.70	1.50
2E + 1.25AC	1.31	1.23	1.17	1.16	1.10	1.09	1.11	1.00	0.90	0.88	1.87
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	1.91	0.69	0.56	0.58	0.66	0.68	0.65	0.83	1.04	1.76	0.63
180 degrees											
Measured Erosion	0.11	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Measured Char	1.04	1.06	1.05	1.01	1.05	1.00	0.98	0.92	0.85	0.82	1.57
Adjusted Char*	0.83	0.85	0.84	0.81	0.84	0.80	0.78	0.74	0.68	0.66	1.26
2E + 1.25AC	1.26	1.22	1.07	1.03	1.05	1.00	0.98	0.92	0.85	0.82	1.97
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.02	0.71	0.71	0.77	0.74	0.83	0.87	0.99	1.16	1.96	0.55
270 degrees											
Measured Erosion	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Measured Char	1.10	1.07	1.04	0.95	0.95	0.91	0.92	0.87	0.86	0.83	1.73
Adjusted Char*	0.88	0.86	0.83	0.76	0.76	0.73	0.74	0.70	0.69	0.66	1.38
2E + 1.25AC	1.20	1.09	1.04	0.95	0.95	0.91	0.92	0.87	0.86	0.83	1.73
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.17	0.91	0.75	0.92	0.93	1.01	0.99	1.11	1.13	1.92	0.76

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{Erosion} + 1.25 \times \text{Adj Char*}} - 1$$

Table 4.12 (continued)

STS-27B Fixed Housing Insulation Erosion and Char Data

Angular Location	Stations										
	0	1	2	3	4	5	6	7	8	9	11
45 degrees											
Measured Erosion	0.07	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.19	0.38
Measured Char	1.07	1.14	1.09	1.08	1.08	1.07	1.07	0.98	0.93	0.67	1.29
Adjusted Char*	0.86	0.91	0.87	0.86	0.86	0.86	0.86	0.78	0.74	0.54	1.03
2E + 1.25AC	1.21	1.22	1.09	1.10	1.08	1.07	1.07	0.98	0.93	1.05	2.05
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.15	0.71	0.67	0.66	0.69	0.71	0.71	0.87	0.97	1.31	0.49
205 degrees											
Measured Erosion	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09
Measured Char	1.02	1.01	0.95	0.91	0.94	0.92	0.97	0.88	0.74	0.63	1.69
Adjusted Char*	0.82	0.81	0.76	0.73	0.75	0.74	0.78	0.70	0.59	0.50	1.35
2E + 1.25AC	1.20	1.03	0.95	0.91	0.94	0.92	0.97	0.88	0.74	0.67	1.87
RSRM min Liner Thickness	3.807	2.081	1.825	1.827	1.829	1.831	1.832	1.834	1.836	2.426	3.048
Margin of Safety	2.17	1.02	0.92	1.01	0.95	0.99	0.89	1.08	1.48	2.62	0.63

* Measured char adjusted to end of action time

$$\text{Margin of Safety} = \frac{\text{minimum liner thickness}}{2 \times \text{Erosion} + 1.25 \times \text{Adj Char*}} - 1$$

Figure 4.110 STS-27B Bearing Protector (90 degrees)

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Figure 4.111 STS-27B Bearing Protector (270 degrees)

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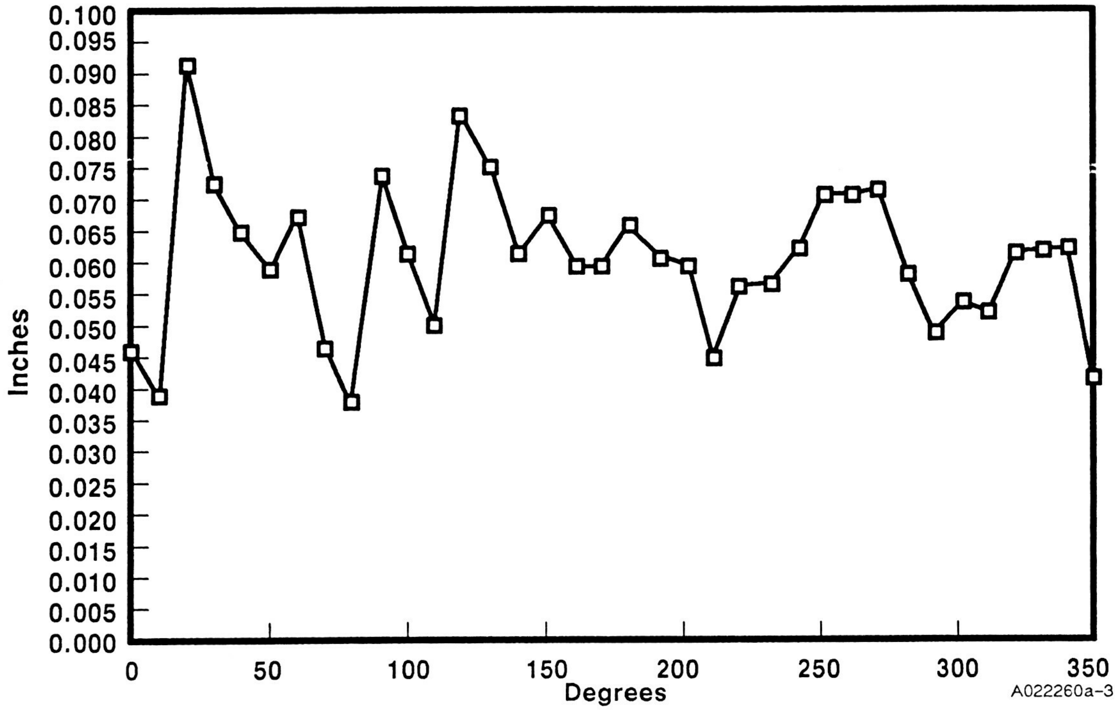

Circumferential Location (deg)	Erosion (in.) in Line With Cowl Vent Holes
0	0.046
10	0.039
20	0.092
30	0.073
40	0.065
50	0.059
60	0.068
70	0.047
80	0.038
90	0.074
100	0.062
110	0.050
120	0.084
130	0.075
140	0.062
150	0.068
160	0.060
170	0.060
180	0.066
190	0.061
200	0.060
210	0.045
220	0.056
230	0.057
240	0.063
250	0.071
260	0.071
270	0.062
280	0.059
290	0.049
300	0.054
310	0.053
320	0.062
330	0.063
340	0.063
350	0.042

Figure 4.112 STS-27B Maximum Bearing Protector Erosion in Line with Cowl Vent Holes

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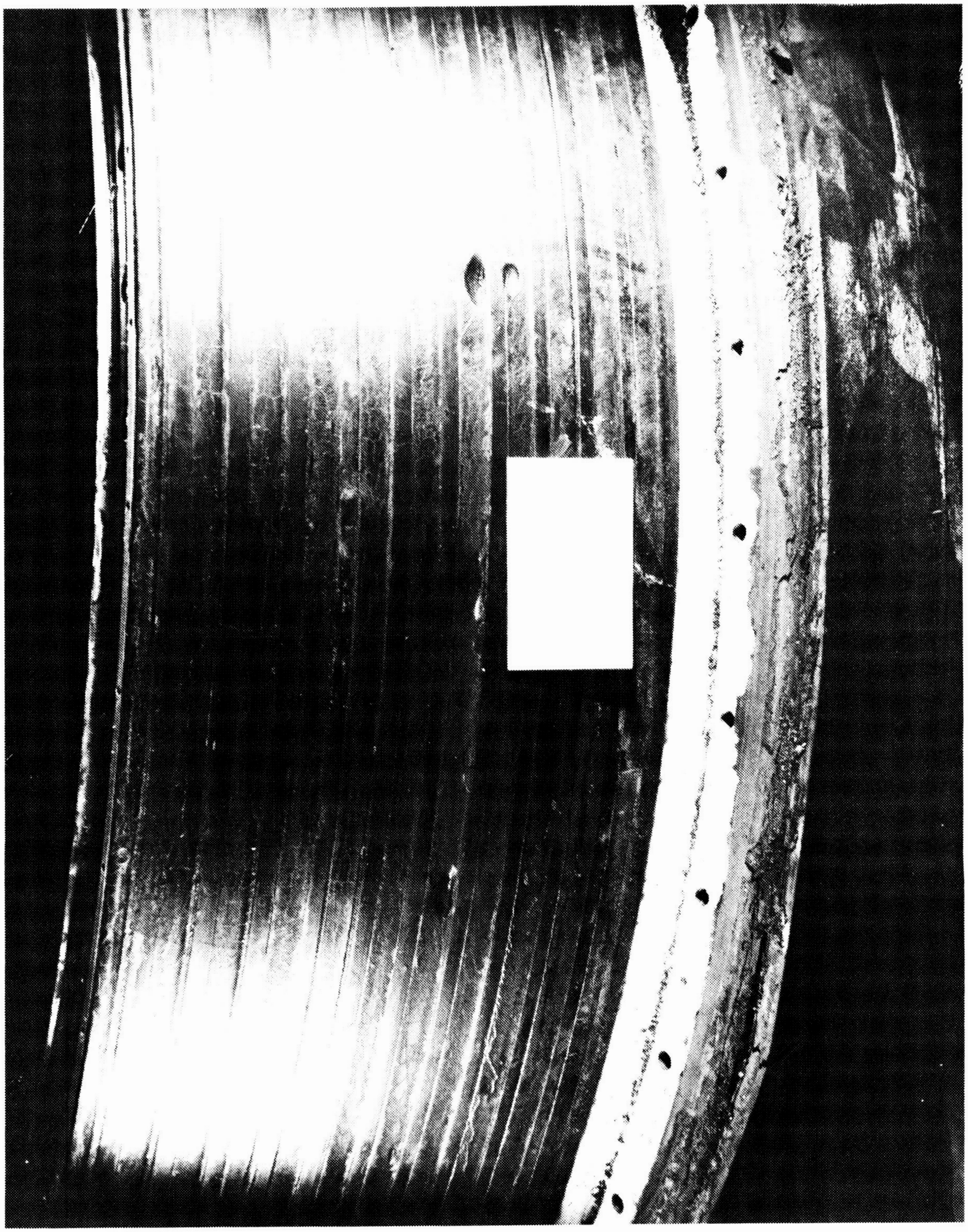

Figure 4.113 STS-27B Flex Bearing Indentations (220 degrees)

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Table 4.13 STS-27B Flex Bearing Pad Indentations

CIRCUMFERENTIAL LOCATION (DEGREES)	RUBBER PAD NO.	RADIAL DEPTH (IN.)	CIRC. LENGTH (IN.)	AXIAL WIDTH (IN.)
200	7	0.50	0.65	0.25
210	7	0.20	1.30	0.45
220	8	0.05	0.60	0.40
220	7	0.30	1.70	0.60
230	8	0.10	0.80	0.50
230	7	0.25	1.35	0.50

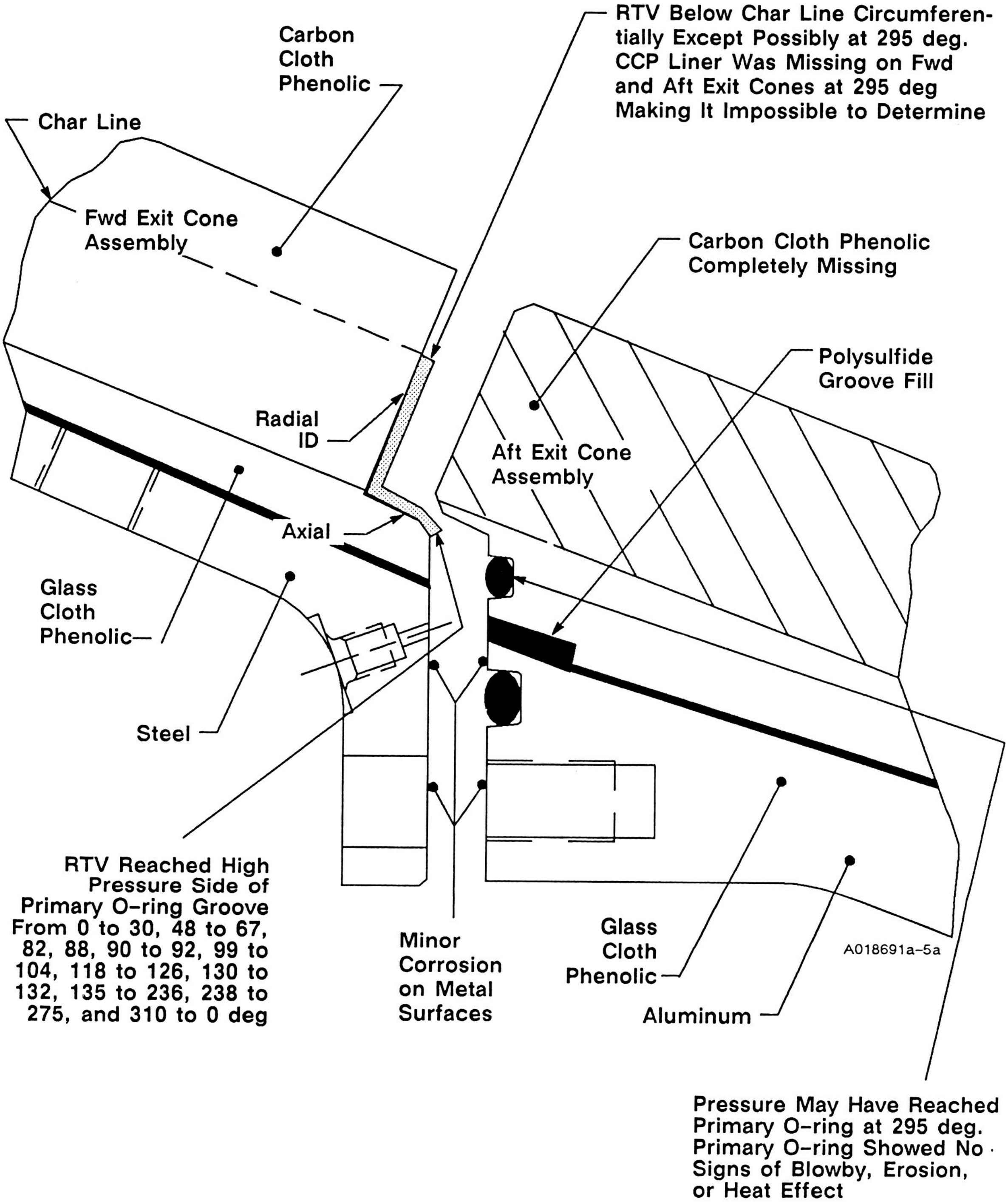

Figure 4.114 STS-27B Forward Exit Cone-to-Aft Exit Cone Joint Interface

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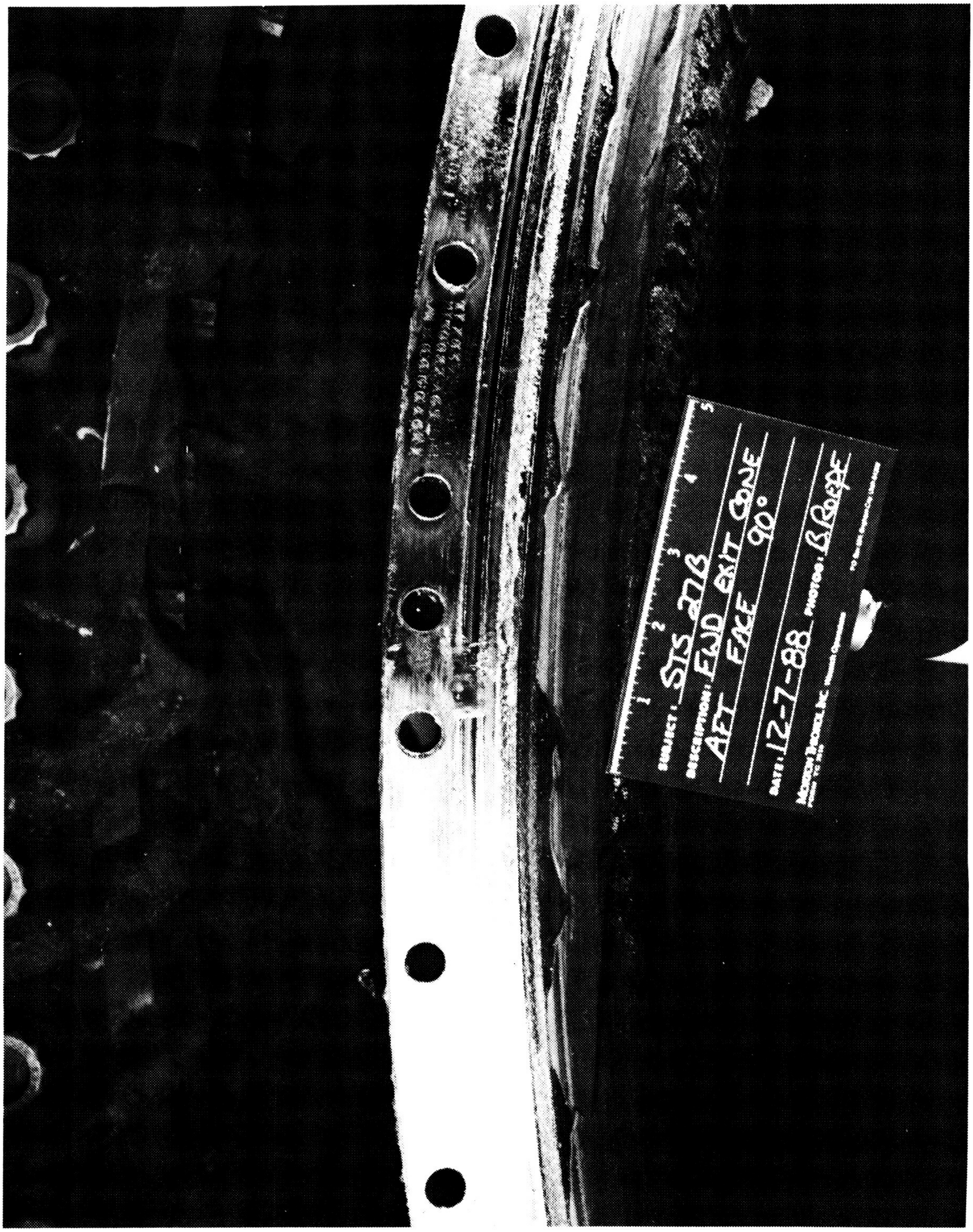

Figure 4.115 STS-27B Joint No. 1 Fwd Exit Cone Aft Face (90 degrees)

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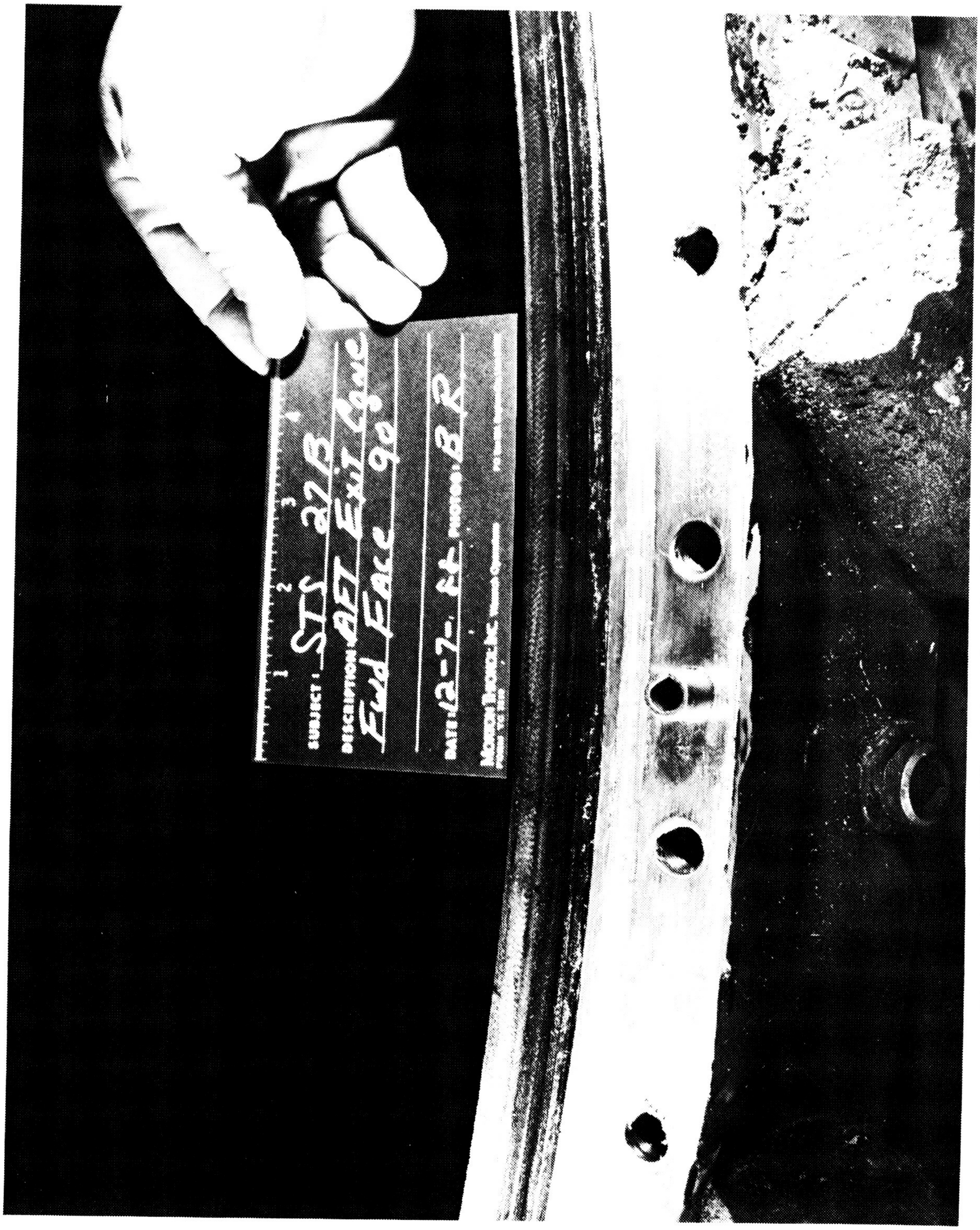

Figure 4.116 STS-27B Joint No. 1 Aft Exit Cone Fwd Face (90 degrees)

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Figure 4.117 STS-27B Joint No. 1 White Substance Believed To Be Salt Mixed with Grease (3 toll degrees)

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Figure 4.118 STS-27B Joint No. 1 Bent Bolt

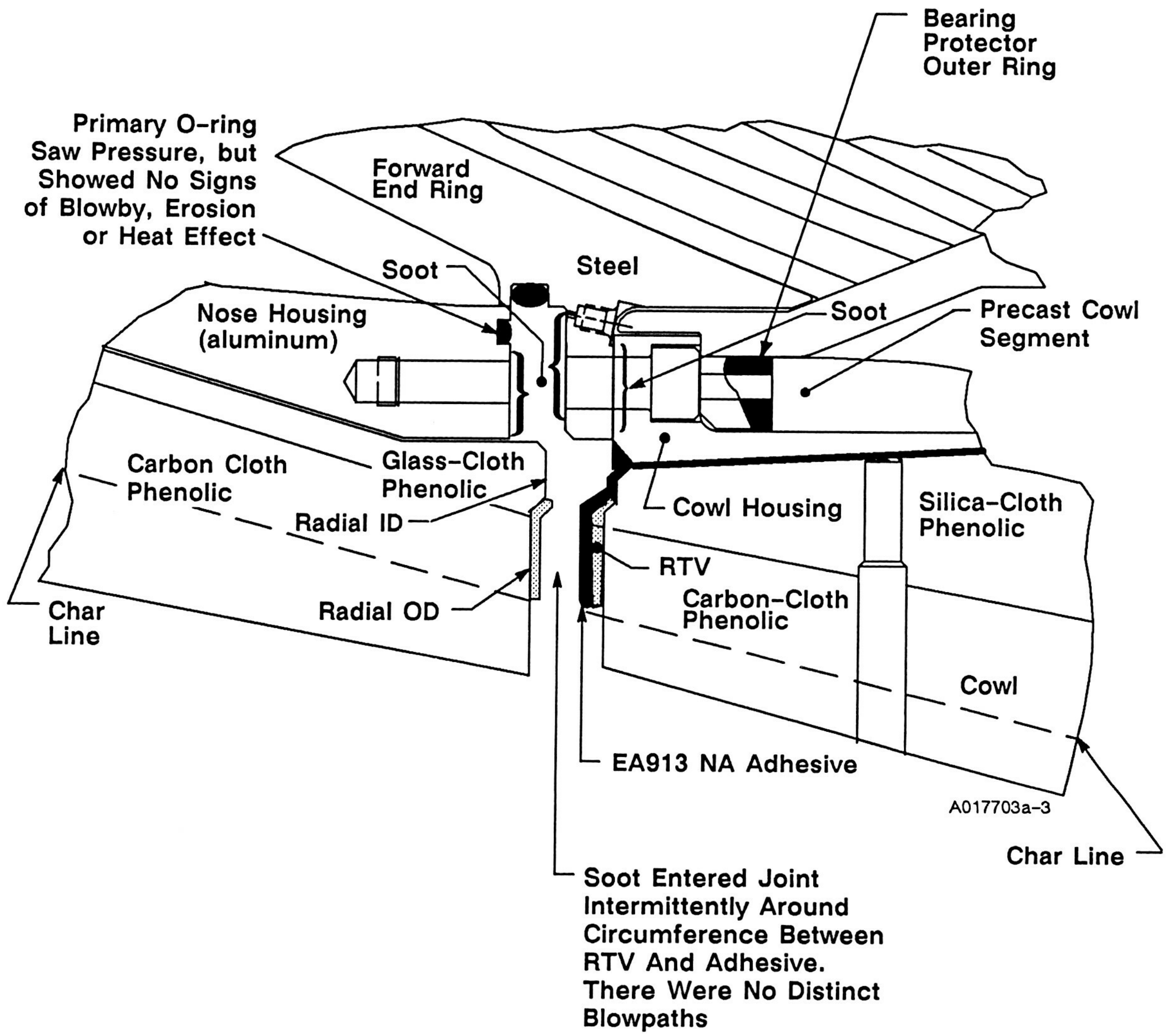

Figure 4.119 STS-27B Nose Inlet Housing/Flex Bearing Joint

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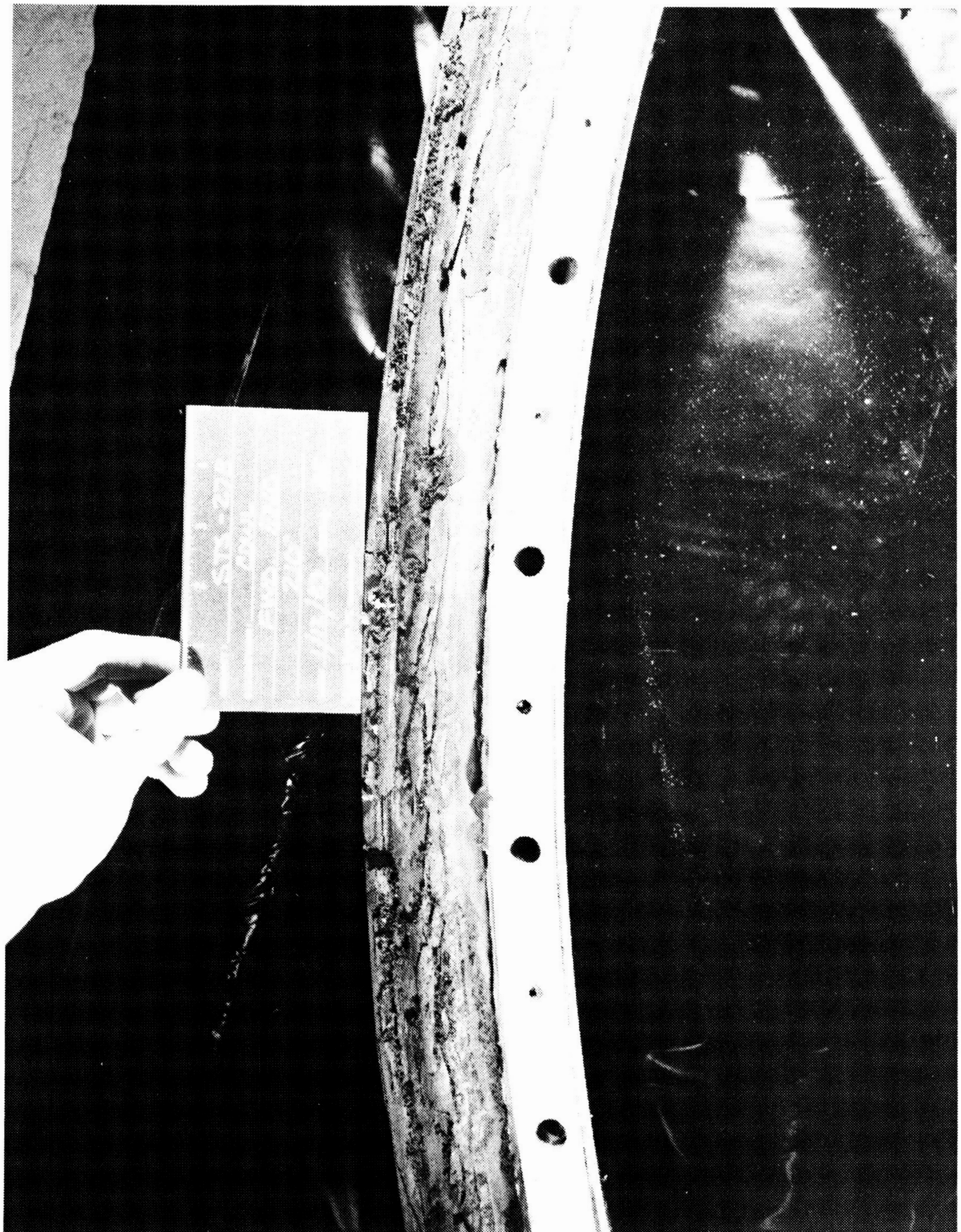

Figure 4.120 STS-27B Joint No. 2 Cowl Fwd End (210 degrees)

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Figure 4.121 STS-27B Joint No. 2 Nose Cap Aft End (210 degrees)

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Figure 4.122 STS-27B Joint No. 2 Nose Cap Aft End with Bearing Removed (210 degrees)

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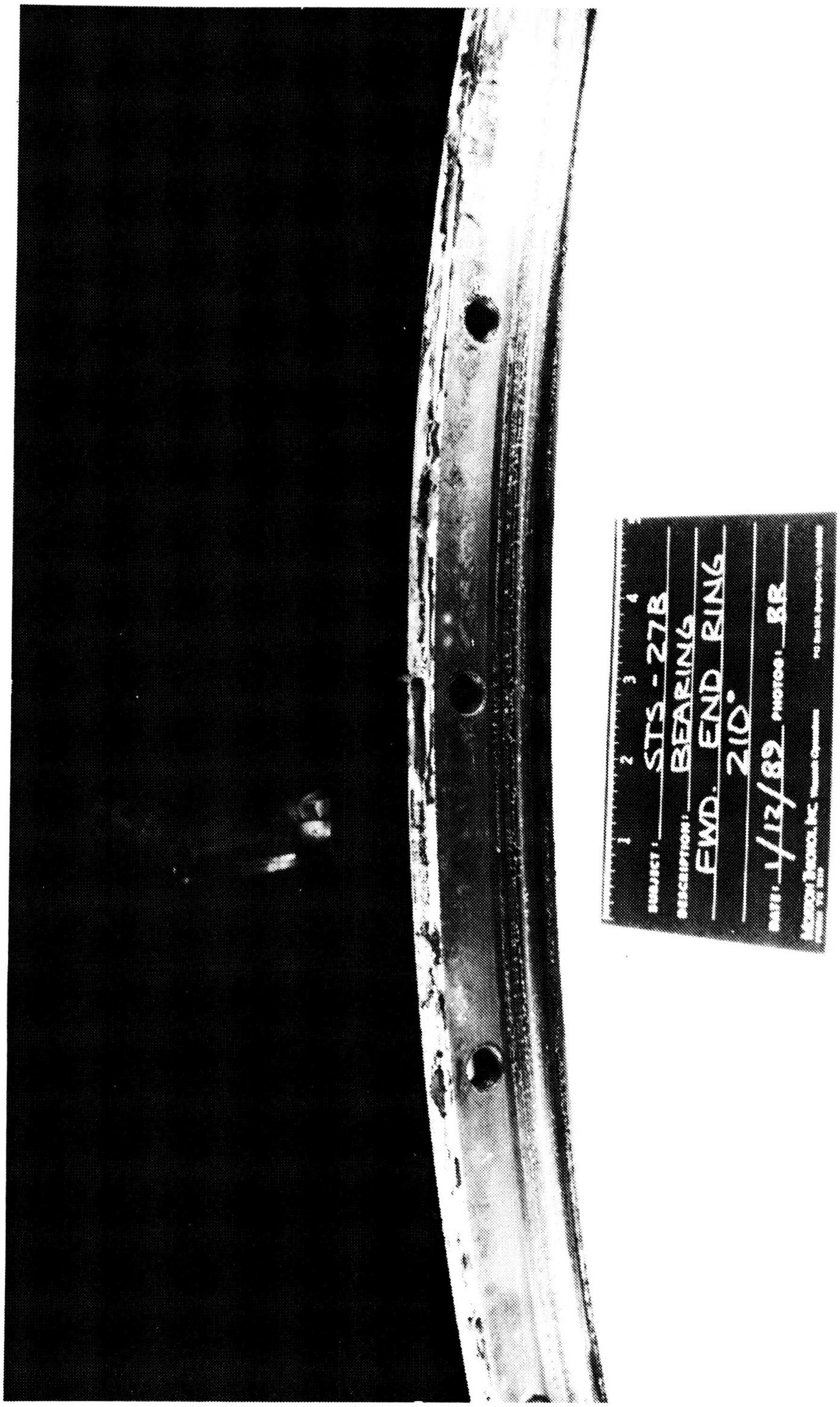

Figure 4.123 STS-27B Joint No. 2 Bearing Fwd End Ring Fwd End (210 degrees)

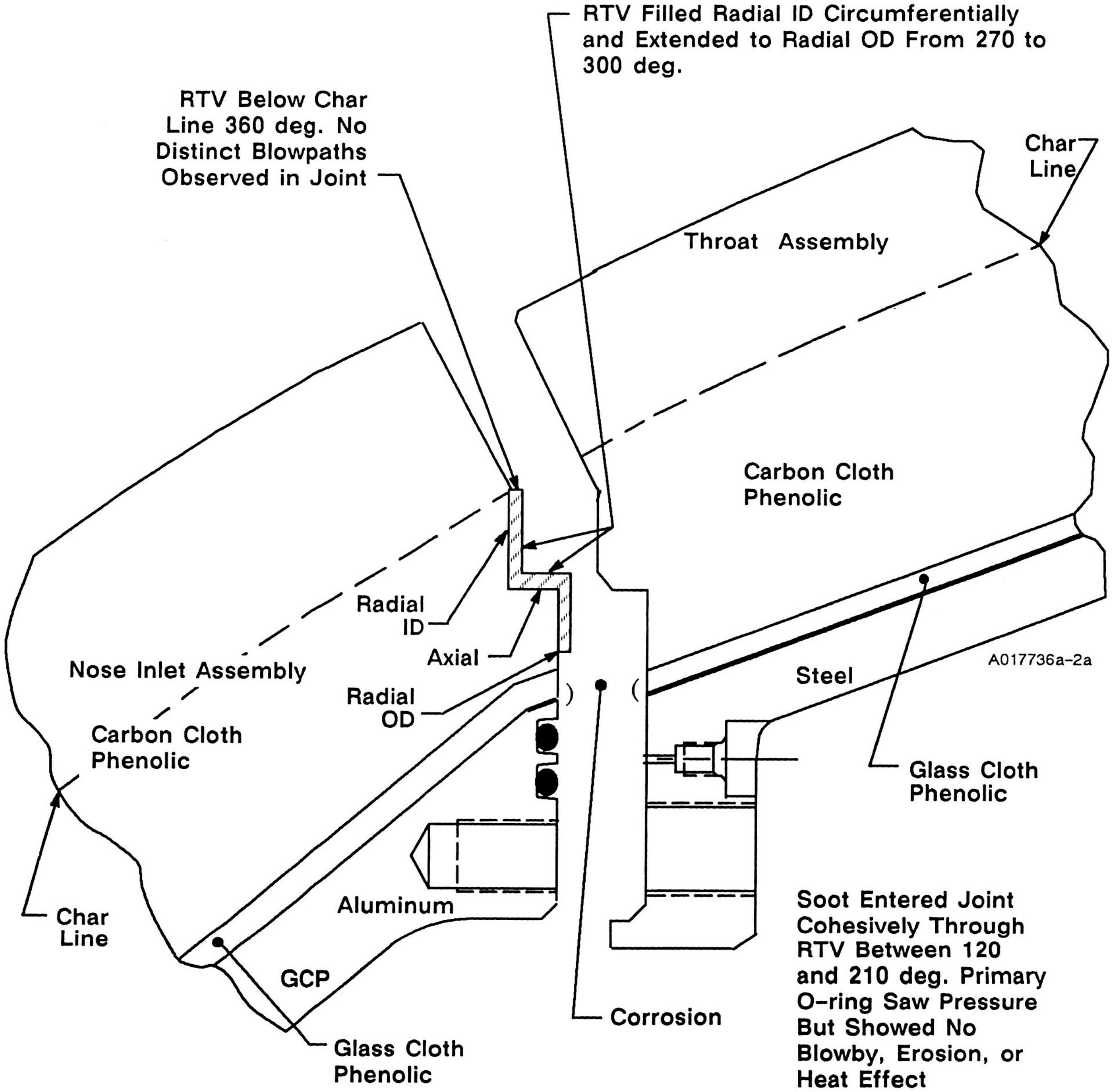

Figure 4.124 STS-27B—Nose Inlet/Throat Housing Joint

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Figure 4.125 STS-27B -504 Ring Aft End (150 degrees)

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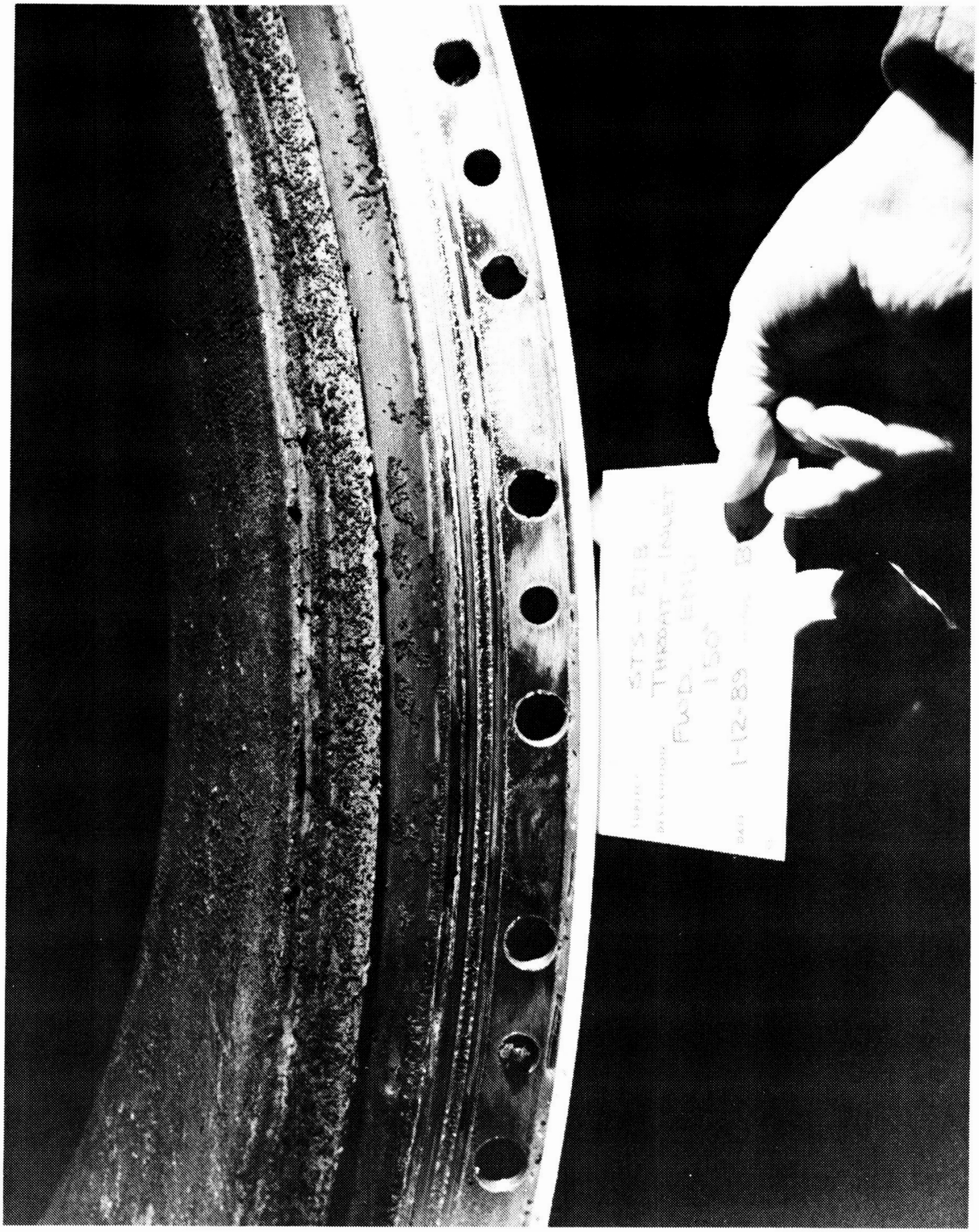

Figure 4.126 STS-27B Throat Inlet Fwd End (150 degrees)

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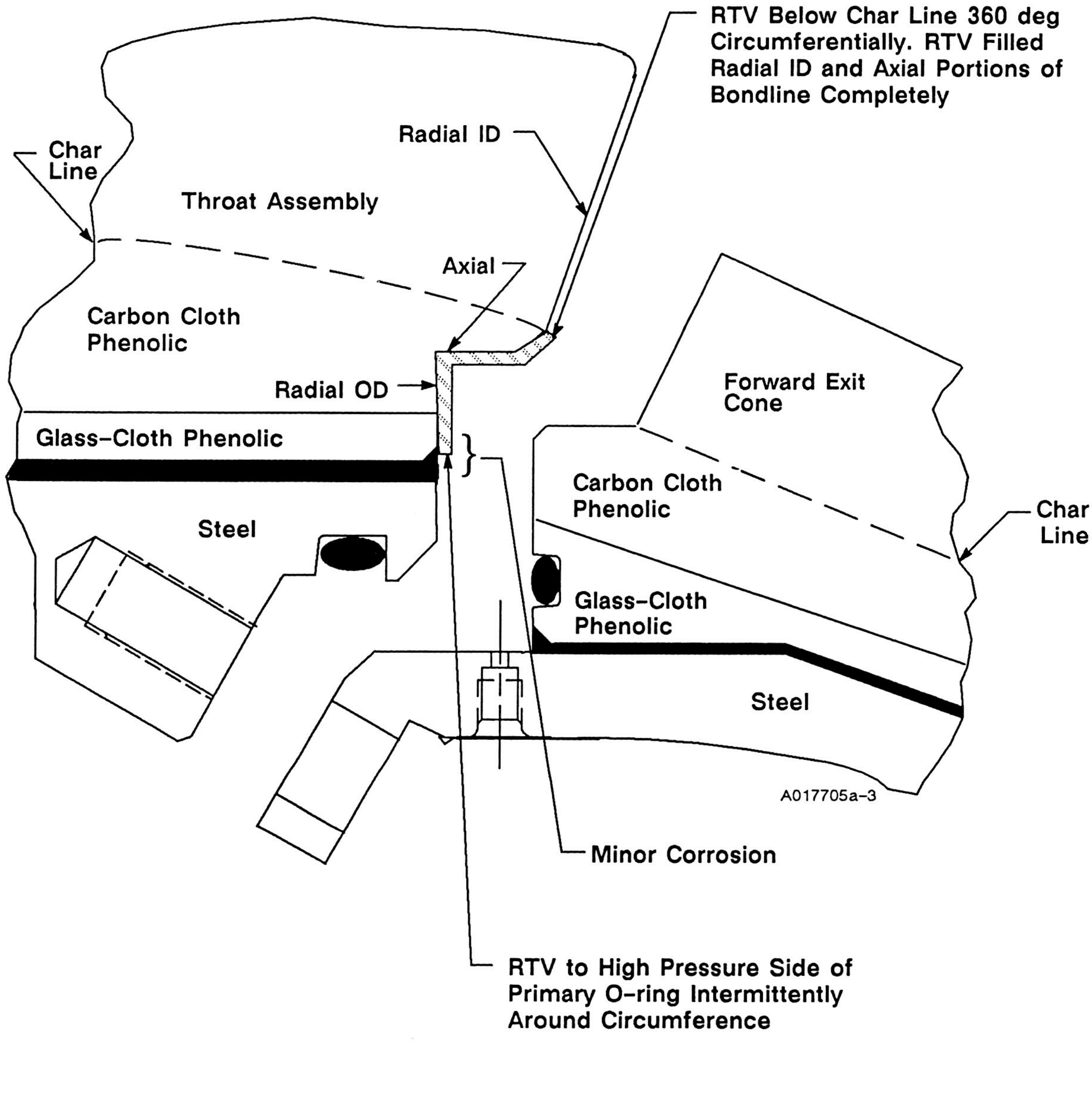

Figure 4.127 STS-27B Throat/Forward Exit Cone Joint

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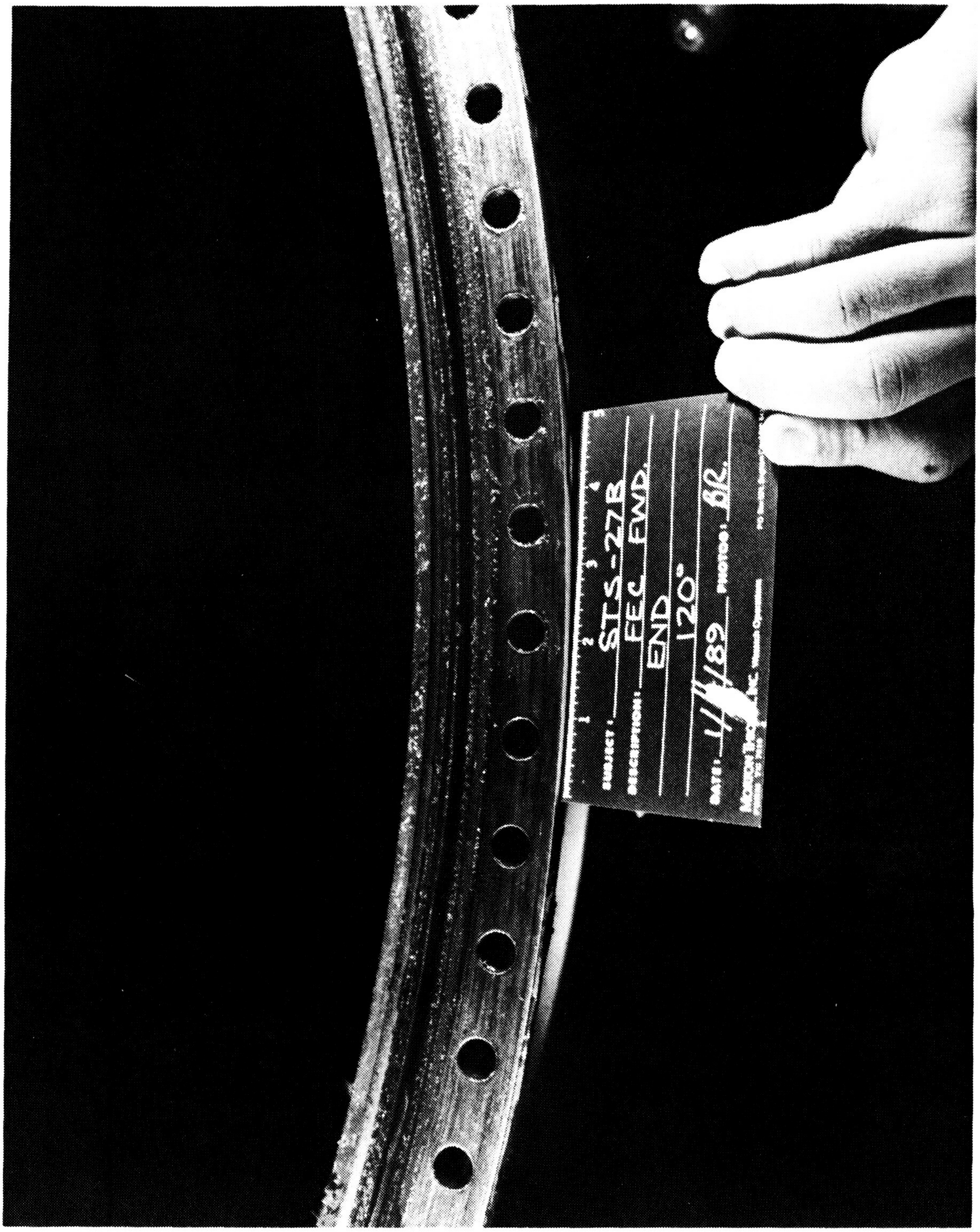

Figure 4.128 STS-27B Forward Exit Cone Fwd End (120 deg)

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Figure 4.129 STS-27B Throat Aft End (120 deg)

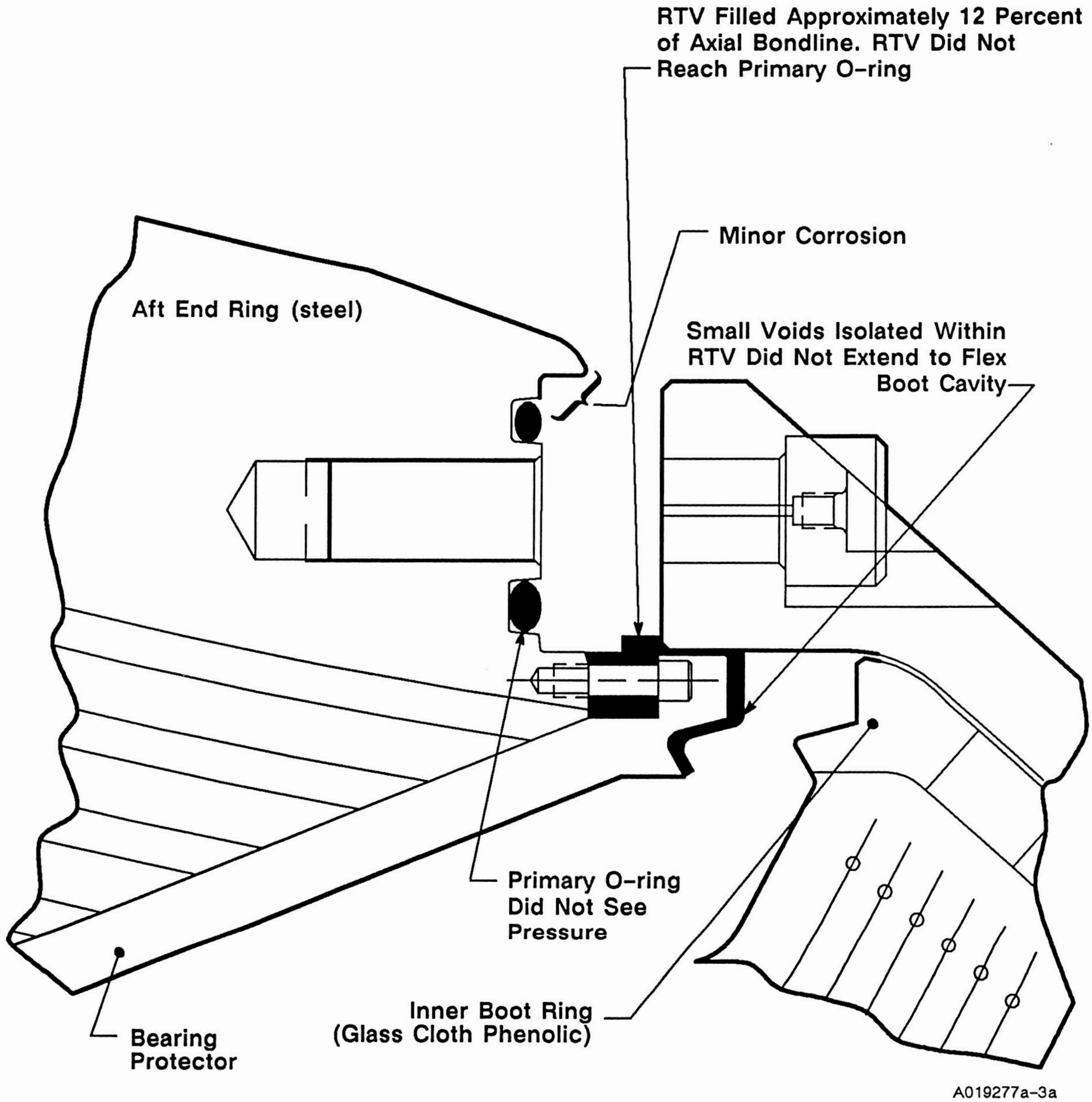

Figure 4.130 STS-27B Flex Bearing/Fixed Housing Joint

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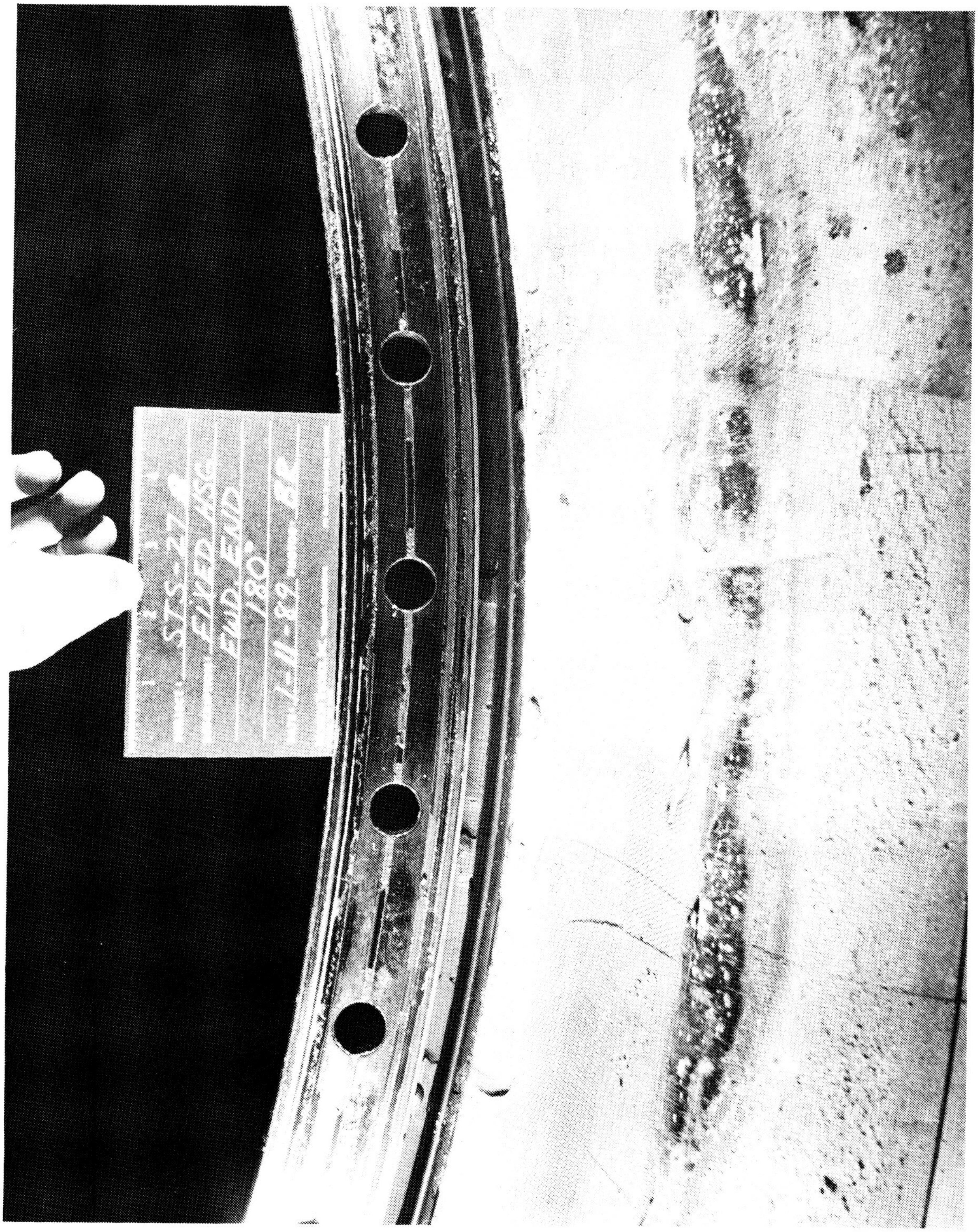

Figure 4.131 STS-27B Fixed Housing Forward End (180 degrees)

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BLACK AND WHITE PHOTOGRAPH

Figure 4.132 STS-27B Aft End Ring Aft End (180 degrees)

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Figure 4.133 STS-27B Joint No.5 Small RTV Voids (210 degrees)

Table 4.14

STS-27 NOZZLE INSTRUMENTATION LOCATION KEY

LOCATION #	GAGE NUMBER		GAGE AZIMUTH (DEGREE)	AXIAL STATION	GAGE DIRECTION	TYPE OF GAGE
1 - FIXED HOUSING AFT END	BO8G*412A		0	1871.8	AXIAL	BIAXIAL
	BO8G*413A		0		TANG	BIAXIAL
	BO8G*417A		90		AXIAL	BIAXIAL
	BO8G*418A		90		TANG	BIAXIAL
	BO8G*422A		180		AXIAL	BIAXIAL
	BO8G*423A		180		TANG	BIAXIAL
	BO8G*427A		270		AXIAL	BIAXIAL
	BO8G*428A		270		TANG	BIAXIAL
4 - AFT END RING FWD END	BO8G*432A		90	1849.0	AXIAL	BIAXIAL
	BO8G*433A		90		TANG	BIAXIAL
7 - NOSE INLET HSG AFT END	BO8G*444A		90	1839.0	AXIAL	BIAXIAL
	BO8G*445A		90		TANG	BIAXIAL
9 - NOSE INLET HSG FWD END	BO8G*442A		90	1827.6	AXIAL	BIAXIAL
	BO8G*443A		90		TANG	BIAXIAL
13 - THROAT HOUSING AFT END	BO8G*446A		90	1849.0	AXIAL	BIAXIAL
	BO8G*447A		90		TANG	BIAXIAL
37 - NOSE INLET HSG FWD END	BO8G*437A		90	1929.2	AXIAL	BIAXIAL
	BO8G*435A	!	90		TANG	BIAXIAL
			THERMOCOUPLE GAGES			
1T - FIXED HOUSING	BO7T*613A		0	1876.6	TEMP.	THERMOCOUPLE
	BO7T*614A		90		TEMP.	THERMOCOUPLE
	BO7T*615A		180		TEMP.	THERMOCOUPLE
	BO7T*616A		270		TEMP.	THERMOCOUPLE
2T - NOSE INLET HSG (FWD END)	BO7T*617A		0	1828.1	TEMP.	THERMOCOUPLE
	BO7T*618A		180		TEMP.	THERMOCOUPLE
3T - THROAT ASSY.	BO7T*620A	!	90	1845.0	TEMP.	THERMOCOUPLE
	BO7T*621A		270		TEMP.	THERMOCOUPLE
4T - AFT EXIT CONE (FWD END)	BO7T*619A		0	1905.0	TEMP.	THERMOCOUPLE
	BO7T*622A		180		TEMP.	THERMOCOUPLE
5T - AFT EXIT CONE (AFT END)	BO7T*623A		0	1996.5	TEMP.	THERMOCOUPLE
	BO7T*624A		120		TEMP.	THERMOCOUPLE
	BO7T*625A		240		TEMP.	THERMOCOUPLE

! = BAD GAGE (NO DATA)

* = BO8G7*** = LEFT SIDE SRB
BO8G8*** = RIGHT SIDE SRB

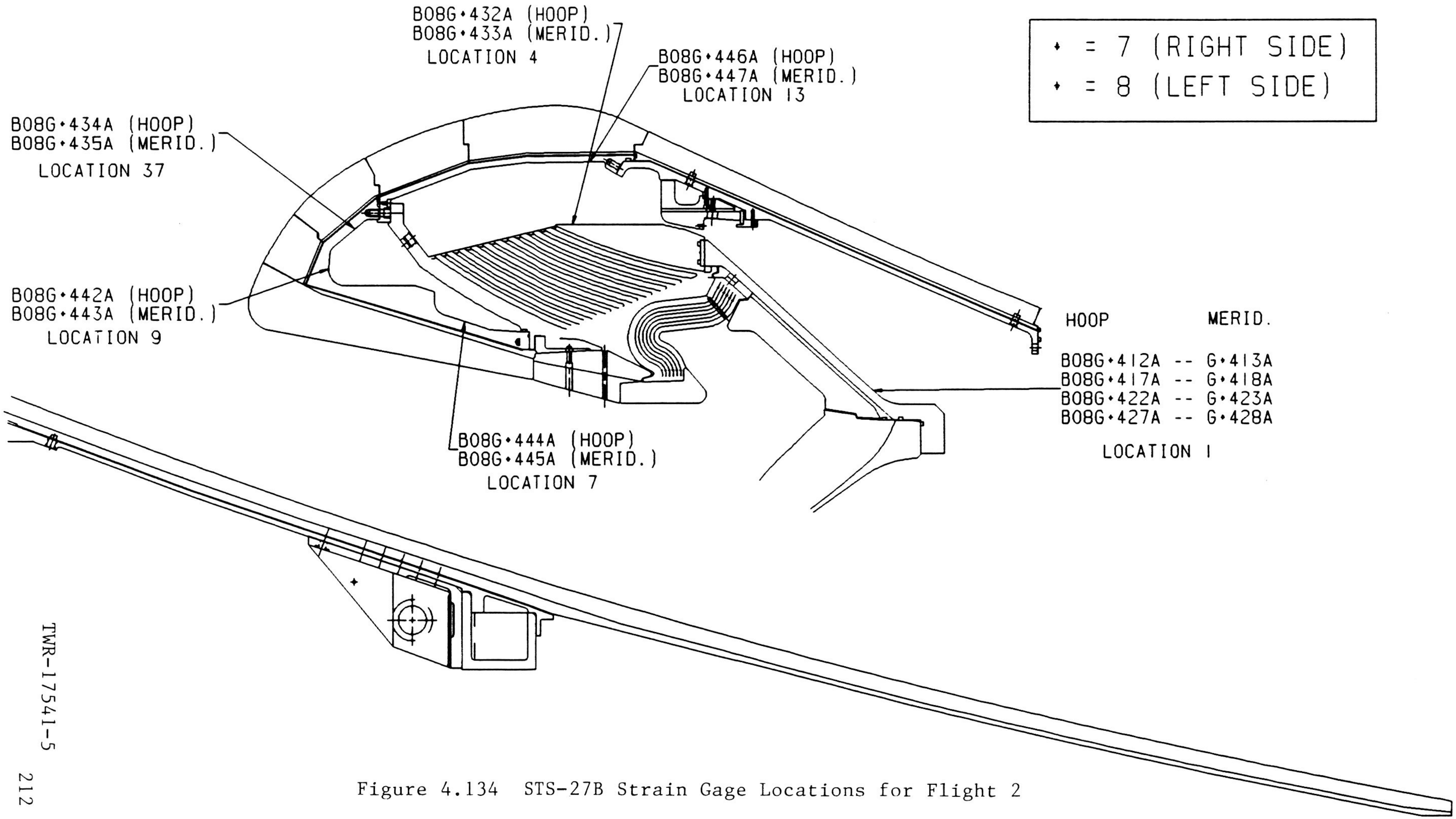


Figure 4.134 STS-27B Strain Gage Locations for Flight 2

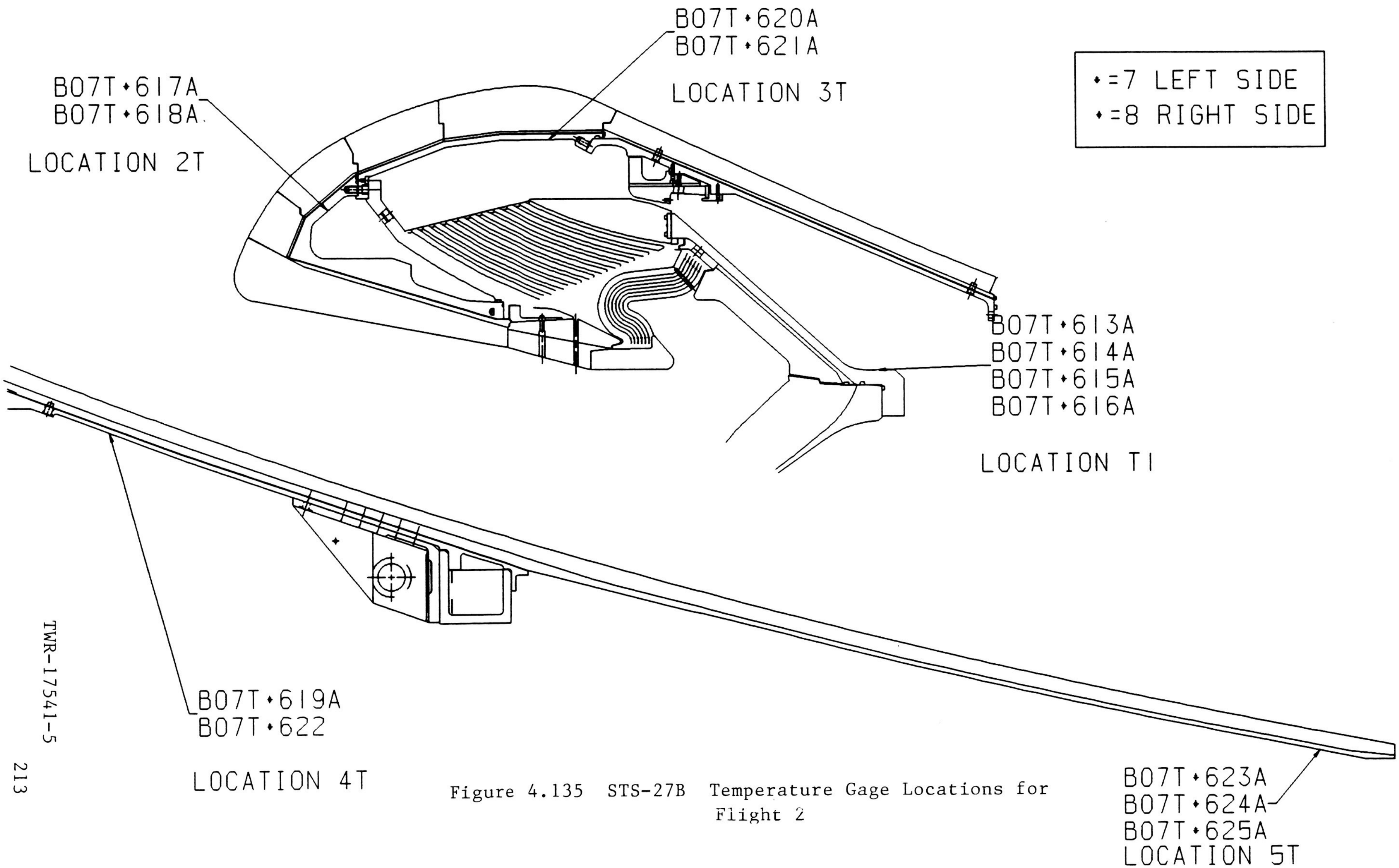
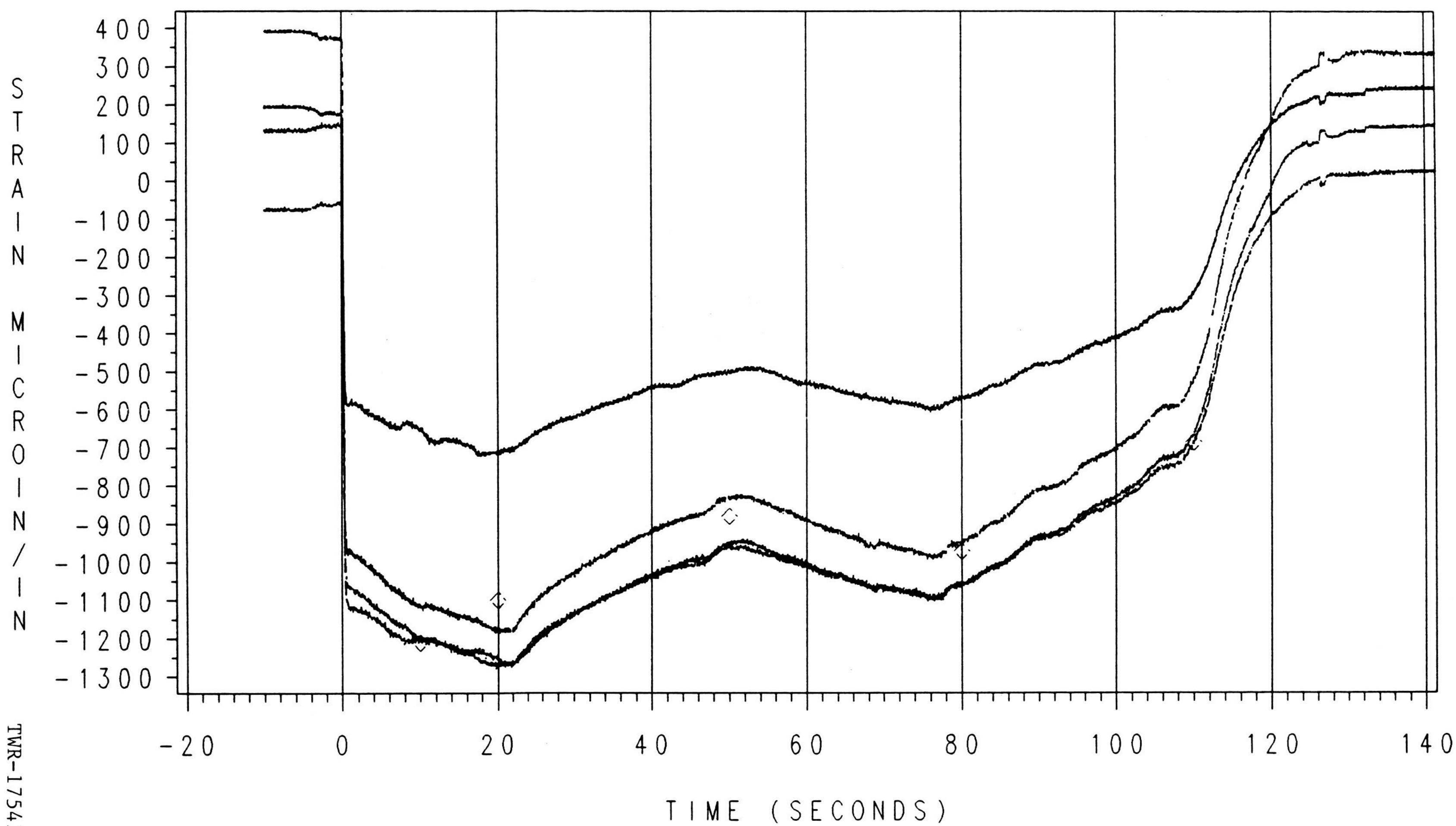


Figure 4.135 STS-27B Temperature Gage Locations for Flight 2

FIXED HSG (AFT END)– RIGHT

STS27 AXIAL STRAINS - LOCATION 1



SOLID LINE=G8412A • 0 DEG
DASHED LINE=G8417A • 90 DEG
DOT-DASHED LINE=G8422A • 180 DEG
LONG-DASHED LINE=G8427A • 270 DEG
SYMBOL = PREDICTED DATA

Figure 4.136 Fixed Housing (Aft End) Right

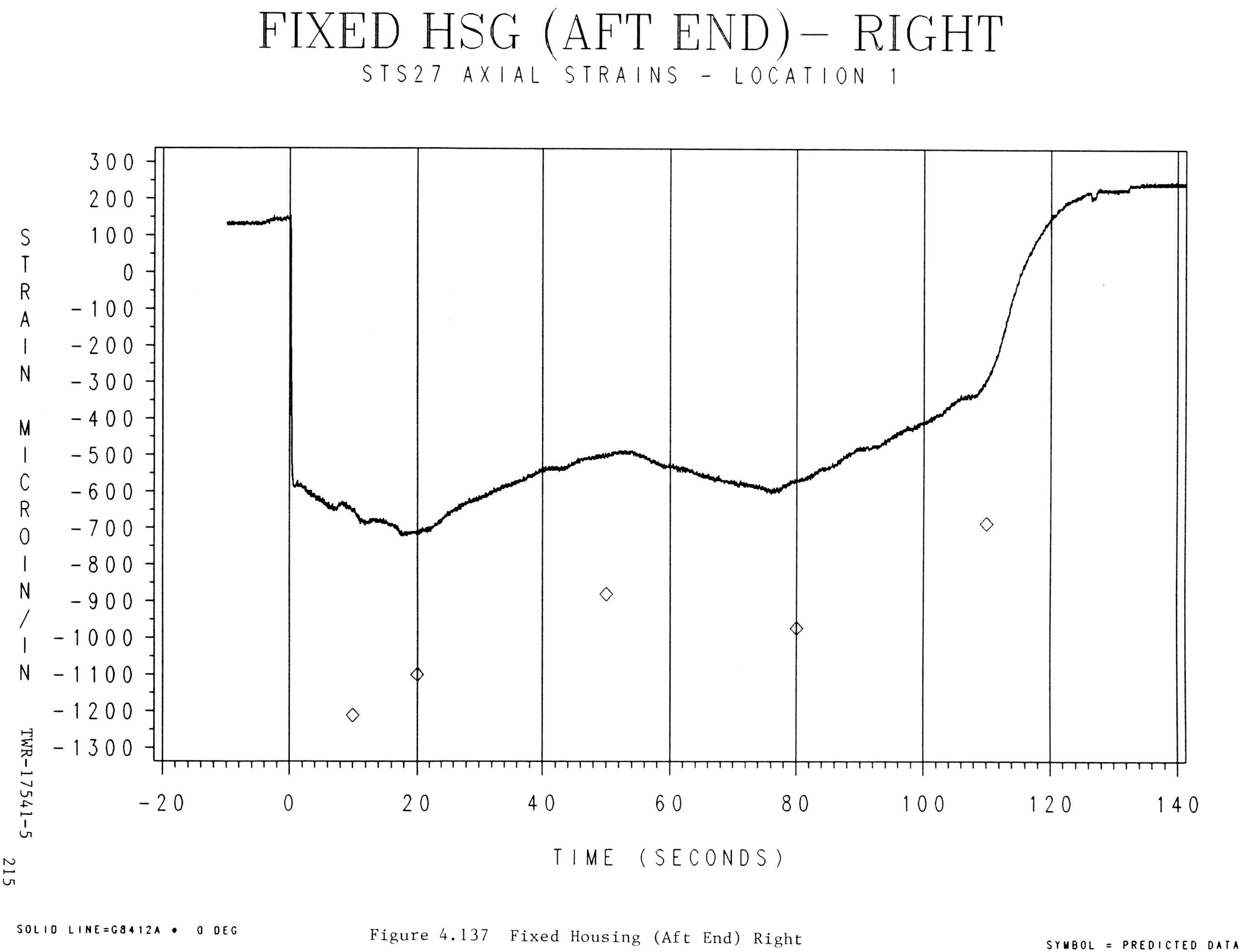


Figure 4.137 Fixed Housing (Aft End) Right

FIXED HSG (AFT END)– RIGHT

STS27 AXIAL STRAINS - LOCATION 1

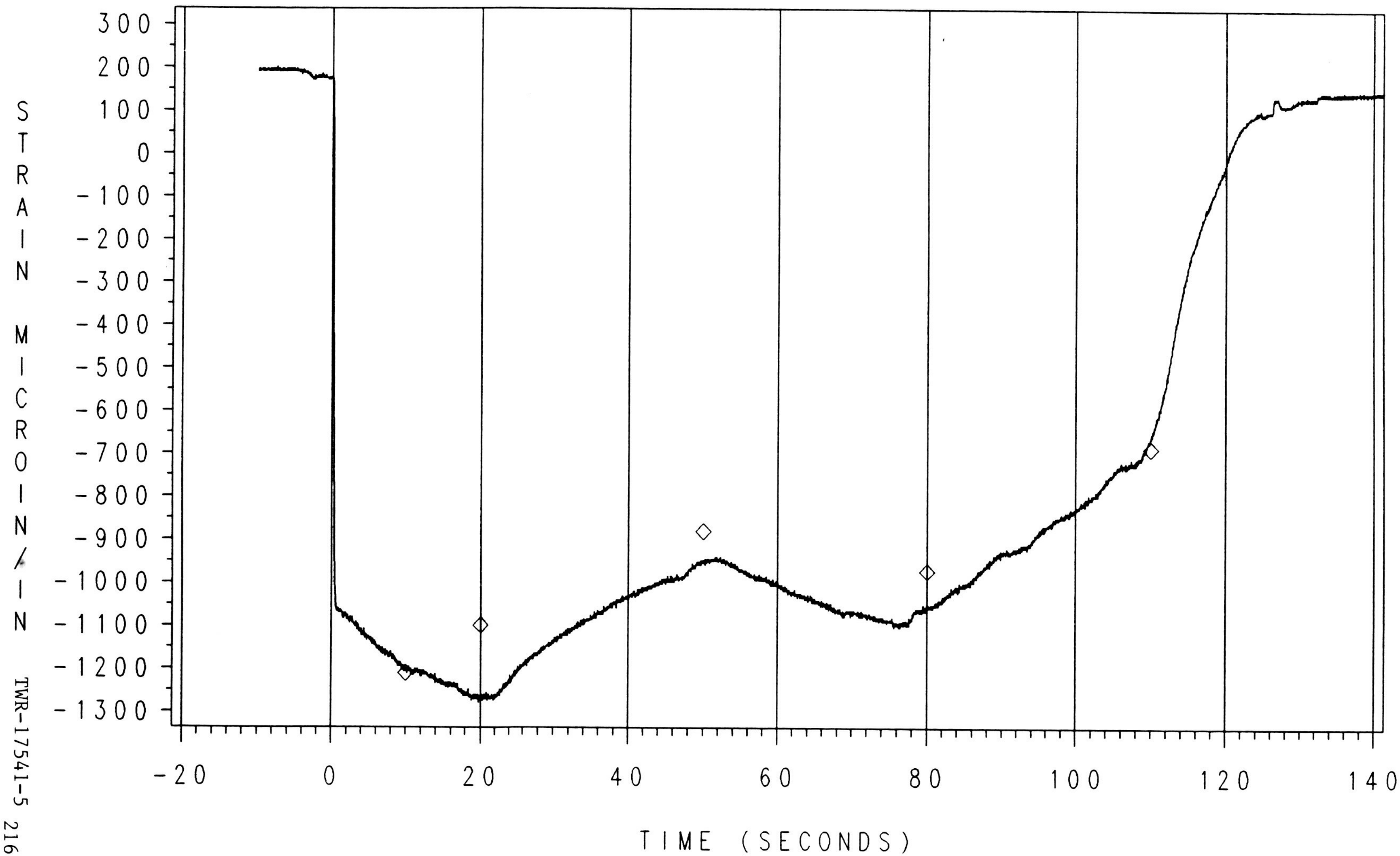


Figure 4.138 Fixed Housing (Aft End) Right

SOLID LINE=G8417A • 90 DEG

SYMBOL = PREDICTED DATA

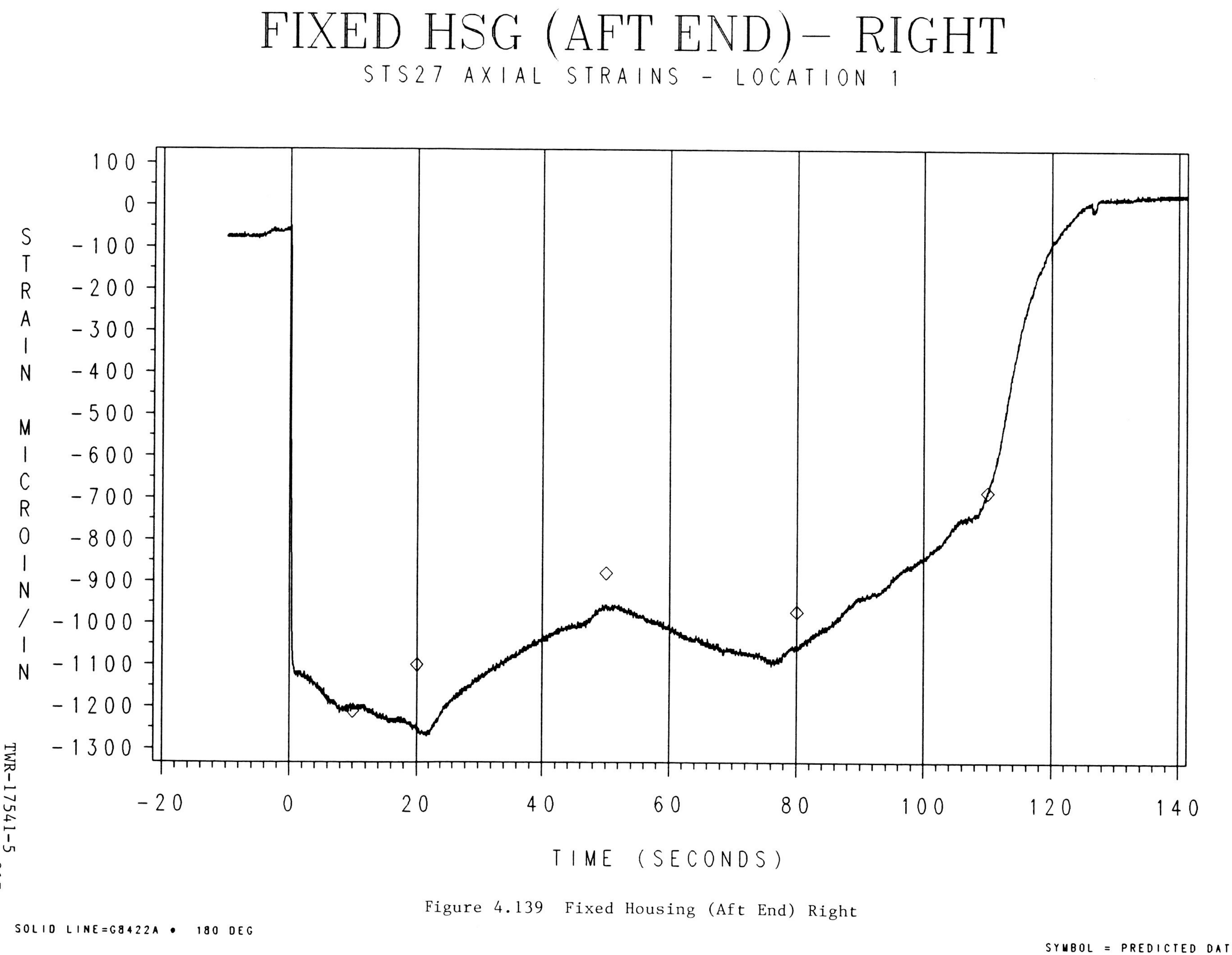


Figure 4.139 Fixed Housing (Aft End) Right

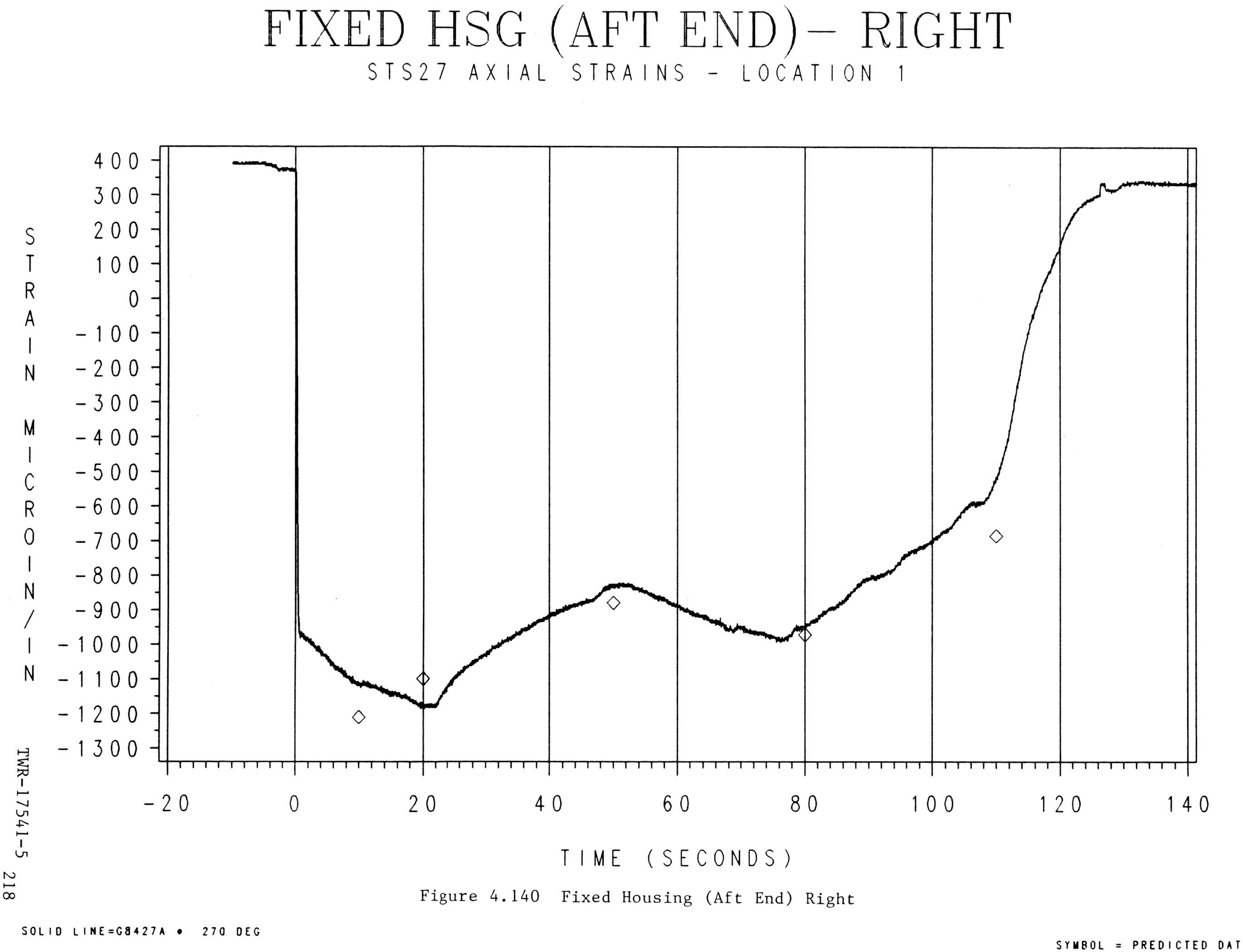


Figure 4.140 Fixed Housing (Aft End) Right

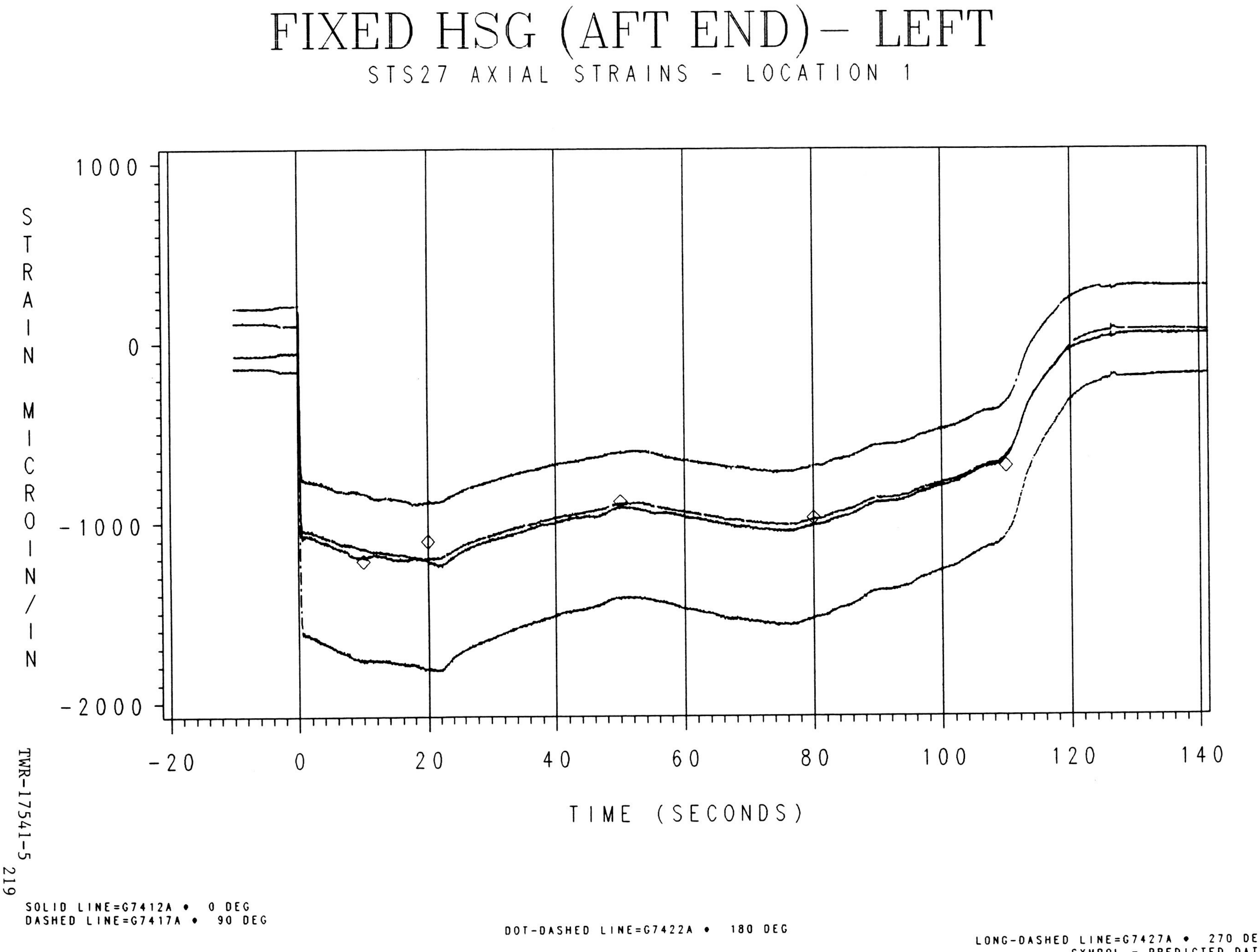


Figure 4.141 Fixed Housing (Aft End) Left

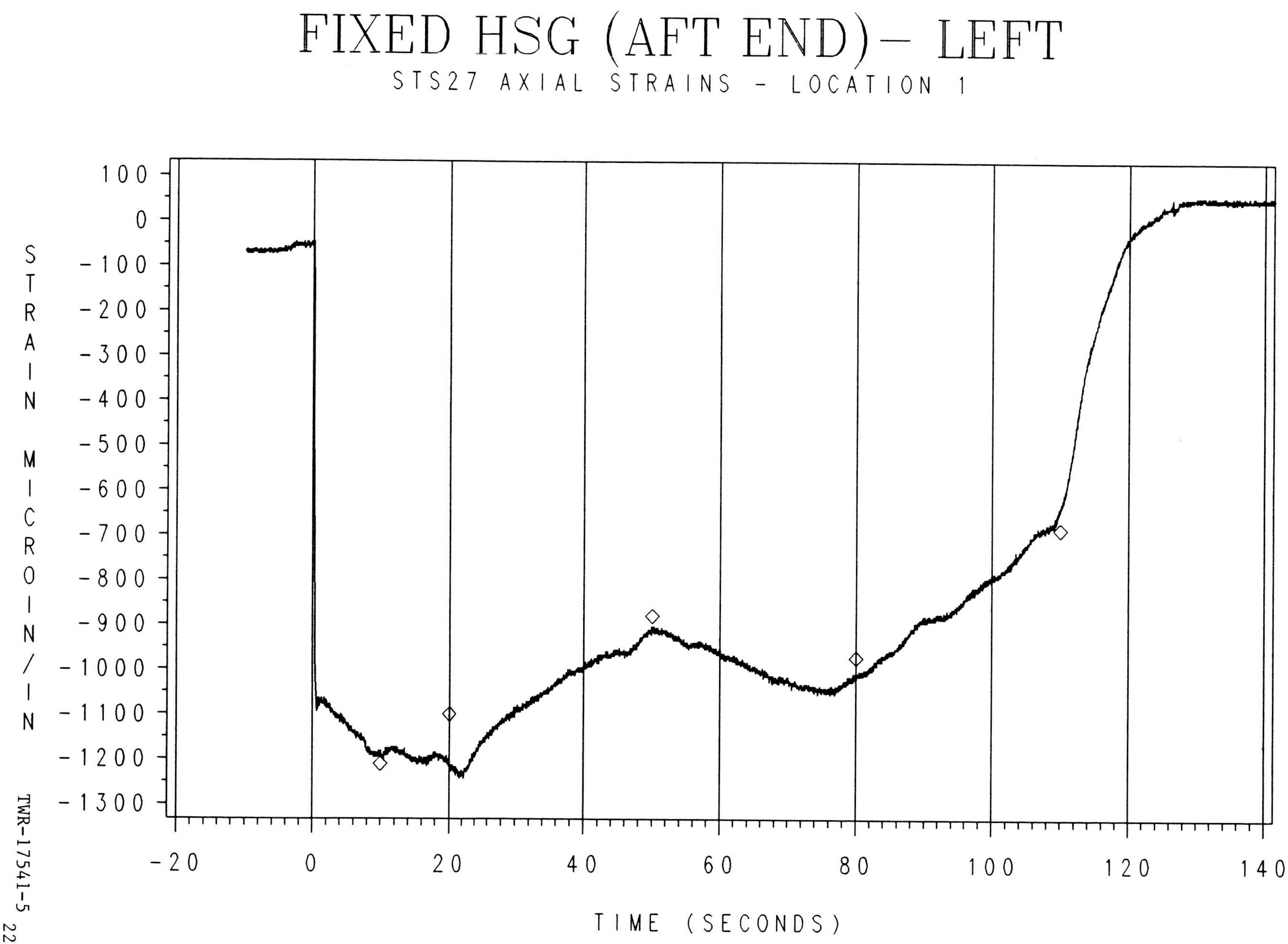


Figure 4.142 Fixed Housing (Aft End) Left

SOLID LINE=G7412A • 0 DEG

SYMBOL = PREDICTED DATA

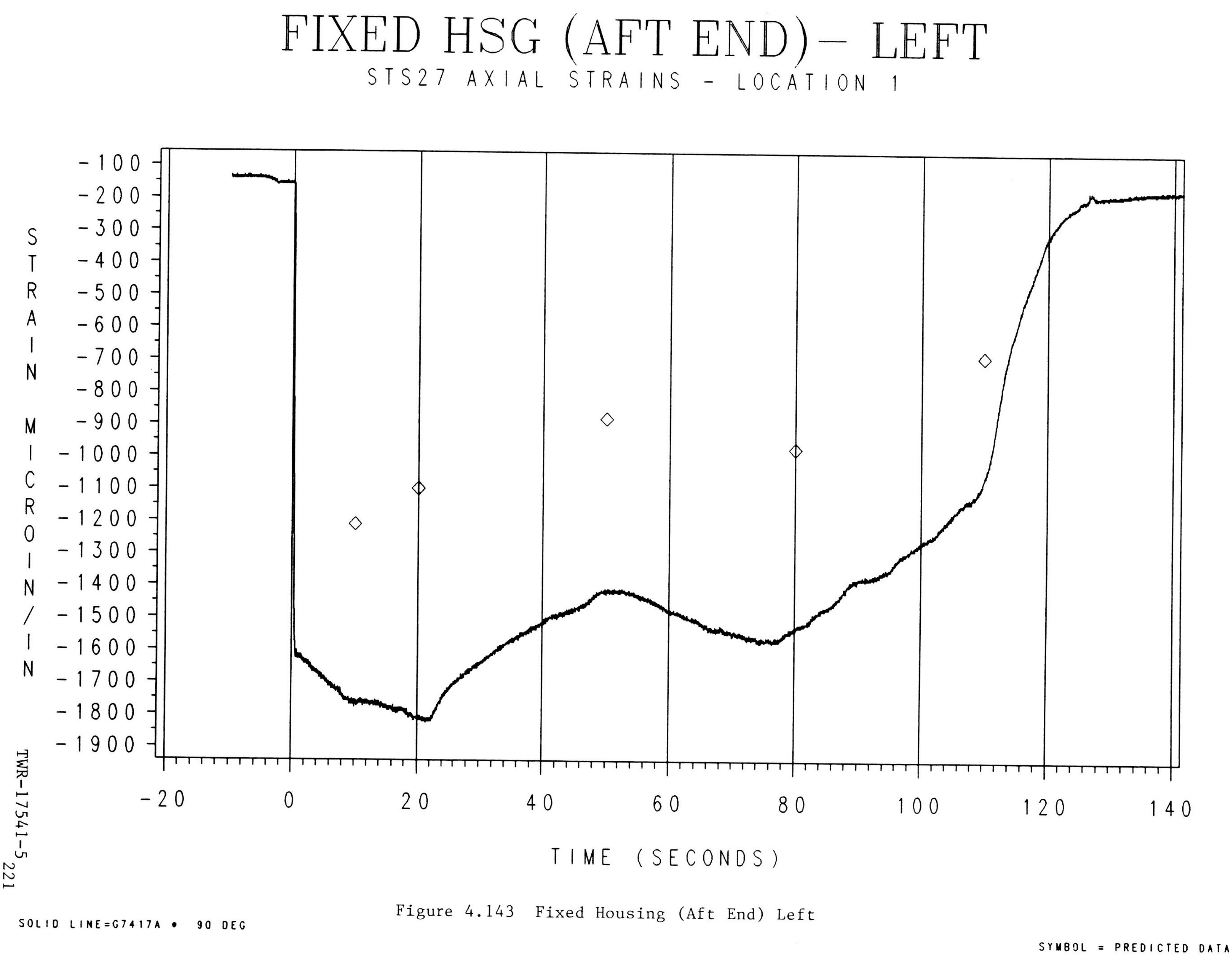


Figure 4.143 Fixed Housing (Aft End) Left

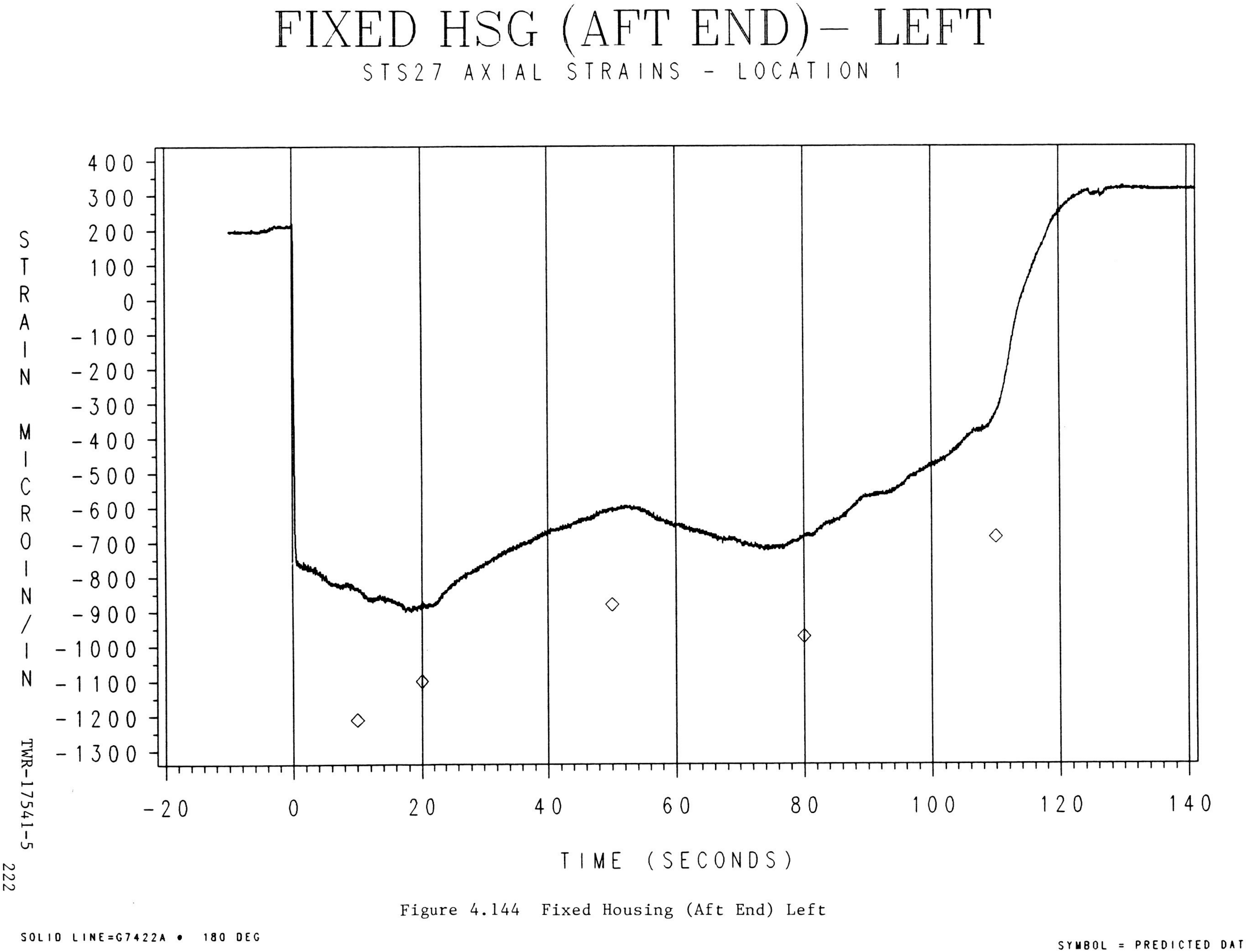
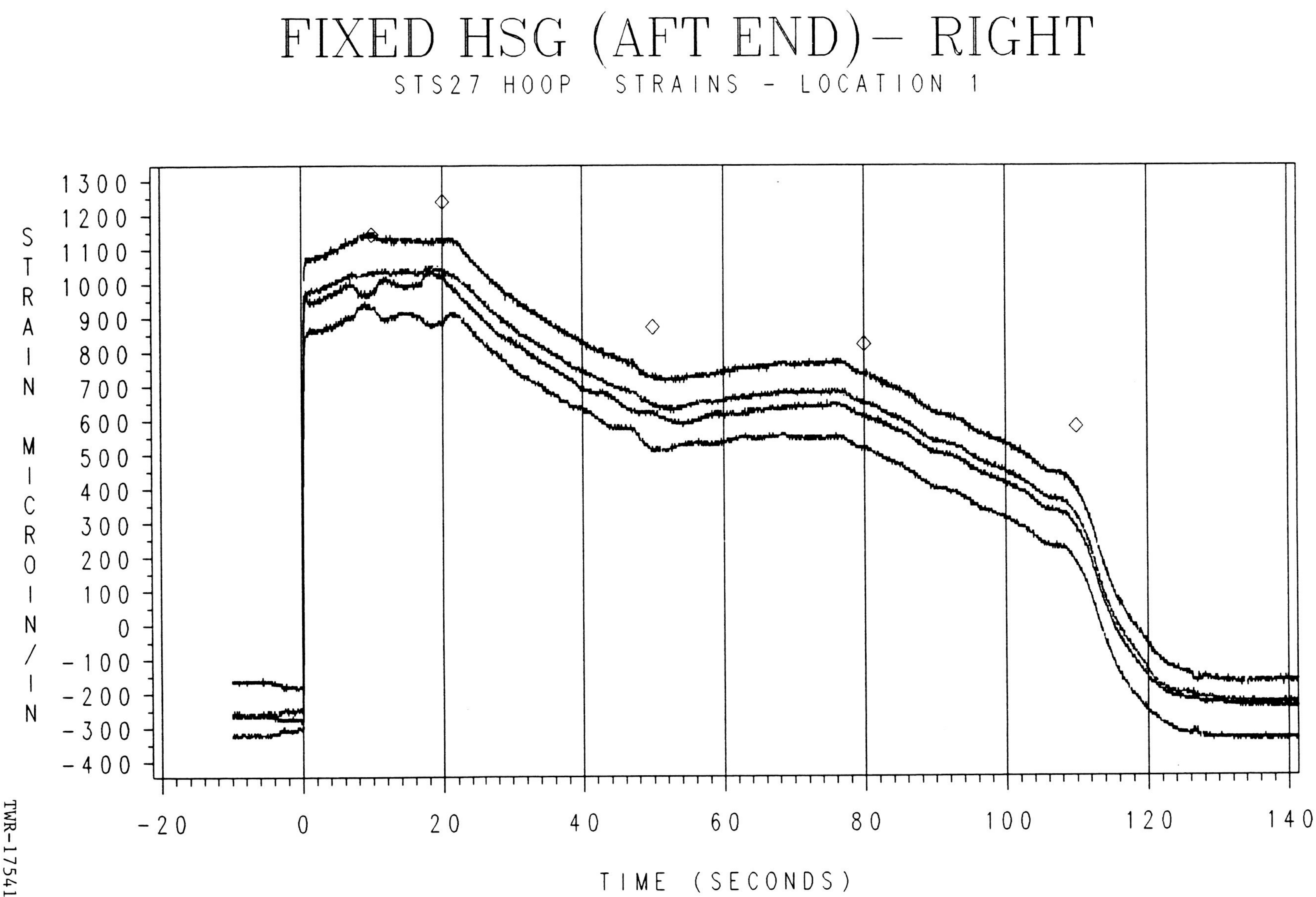


Figure 4.144 Fixed Housing (Aft End) Left



SOLID LINE=G8413A • 0 DEG
DASHED LINE=G8418A • 90 DEG
DOT-DASHED LINE=G8423A • 180 DEG
LONG-DASHED LINE=G8428A • 270 DEG
SYMBOL = PREDICTED DATA

Figure 4.145 Fixed Housing (Aft End) Right

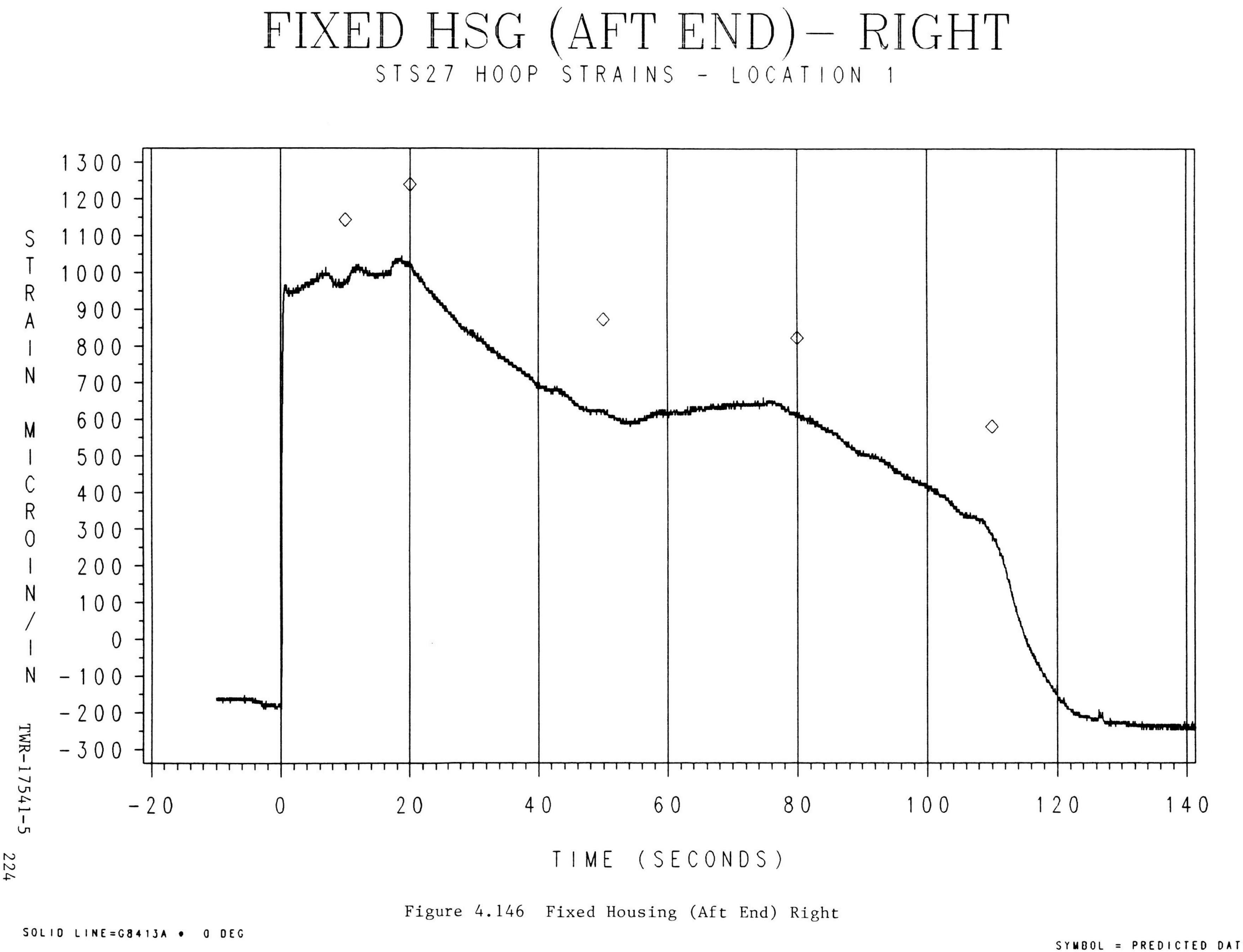


Figure 4.146 Fixed Housing (Aft End) Right

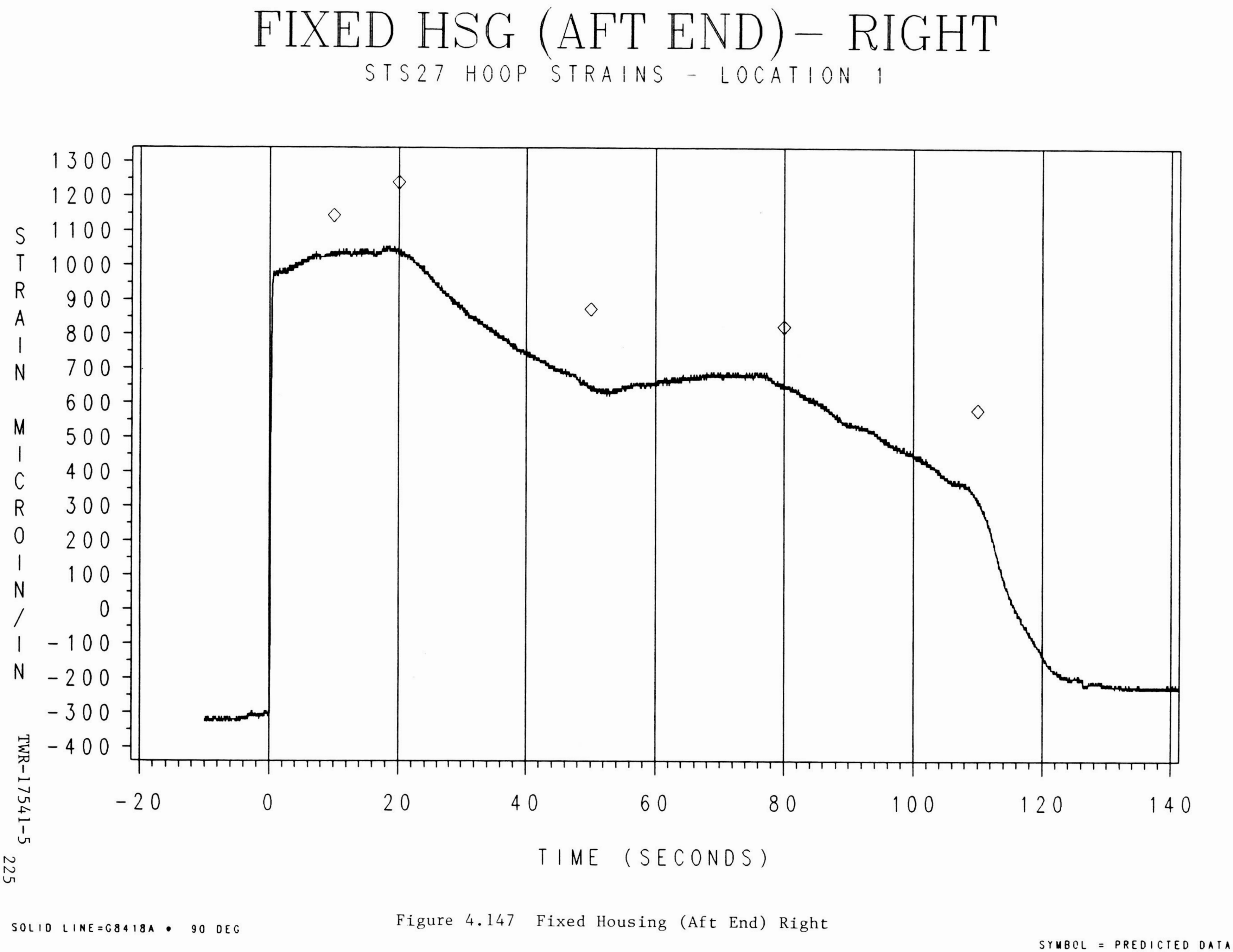


Figure 4.147 Fixed Housing (Aft End) Right

FIXED HSG (AFT END) – RIGHT

STS27 HOOP STRAINS - LOCATION 1

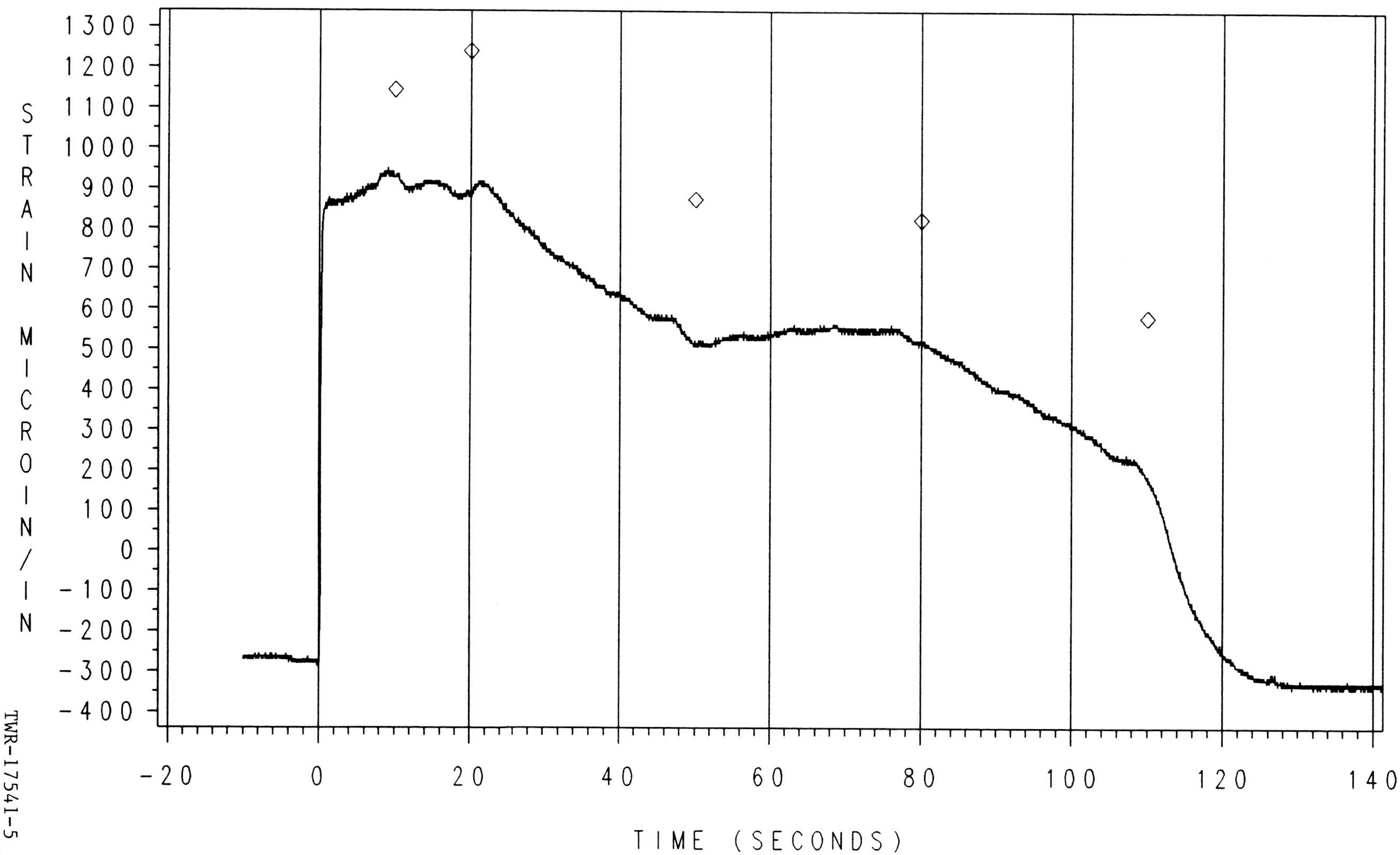


Figure 4.148 Fixed Housing (Aft End) Right

SOLID LINE=G8423A • 180 DEG

SYMBOL = PREDICTED DATA

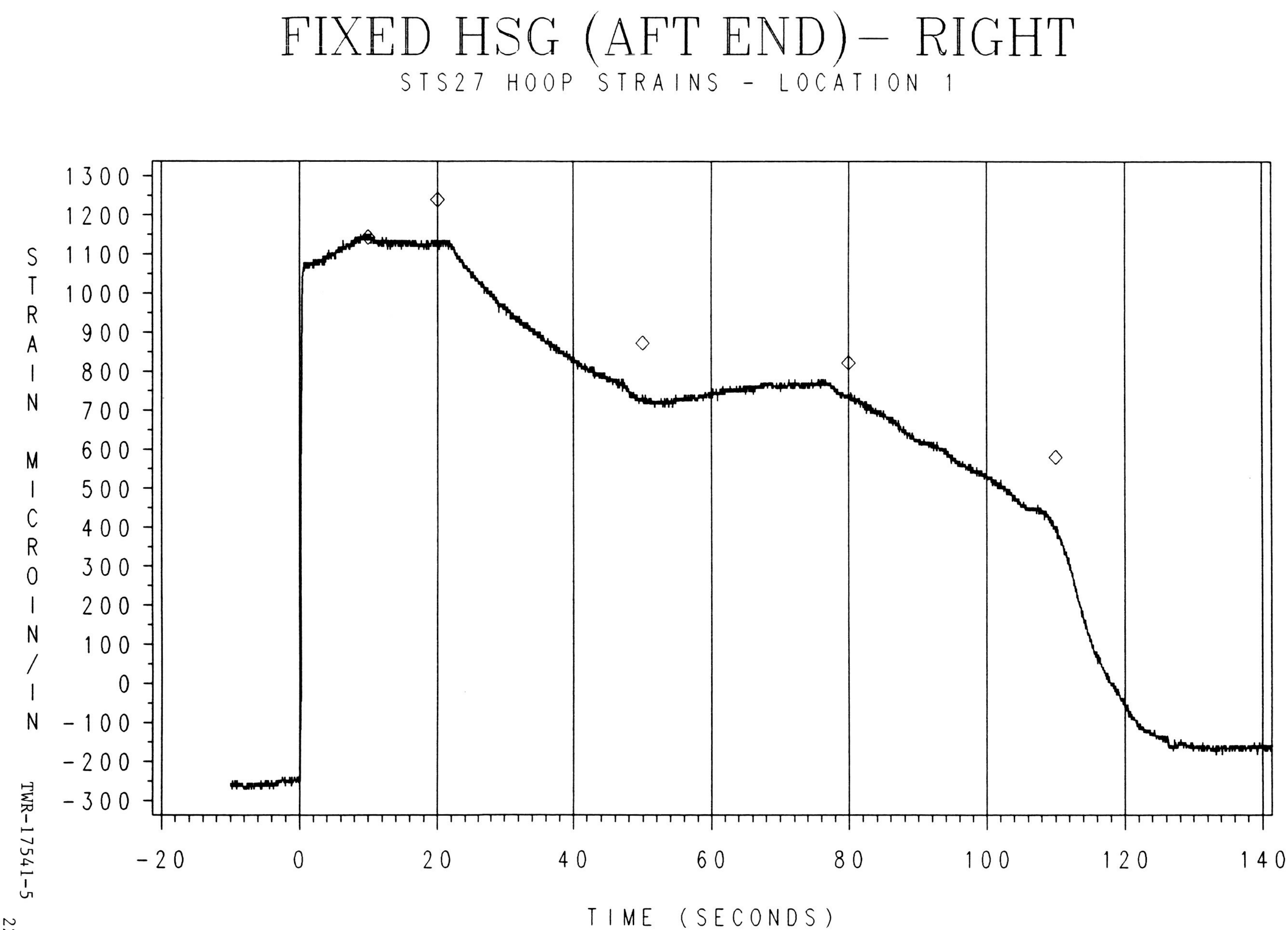


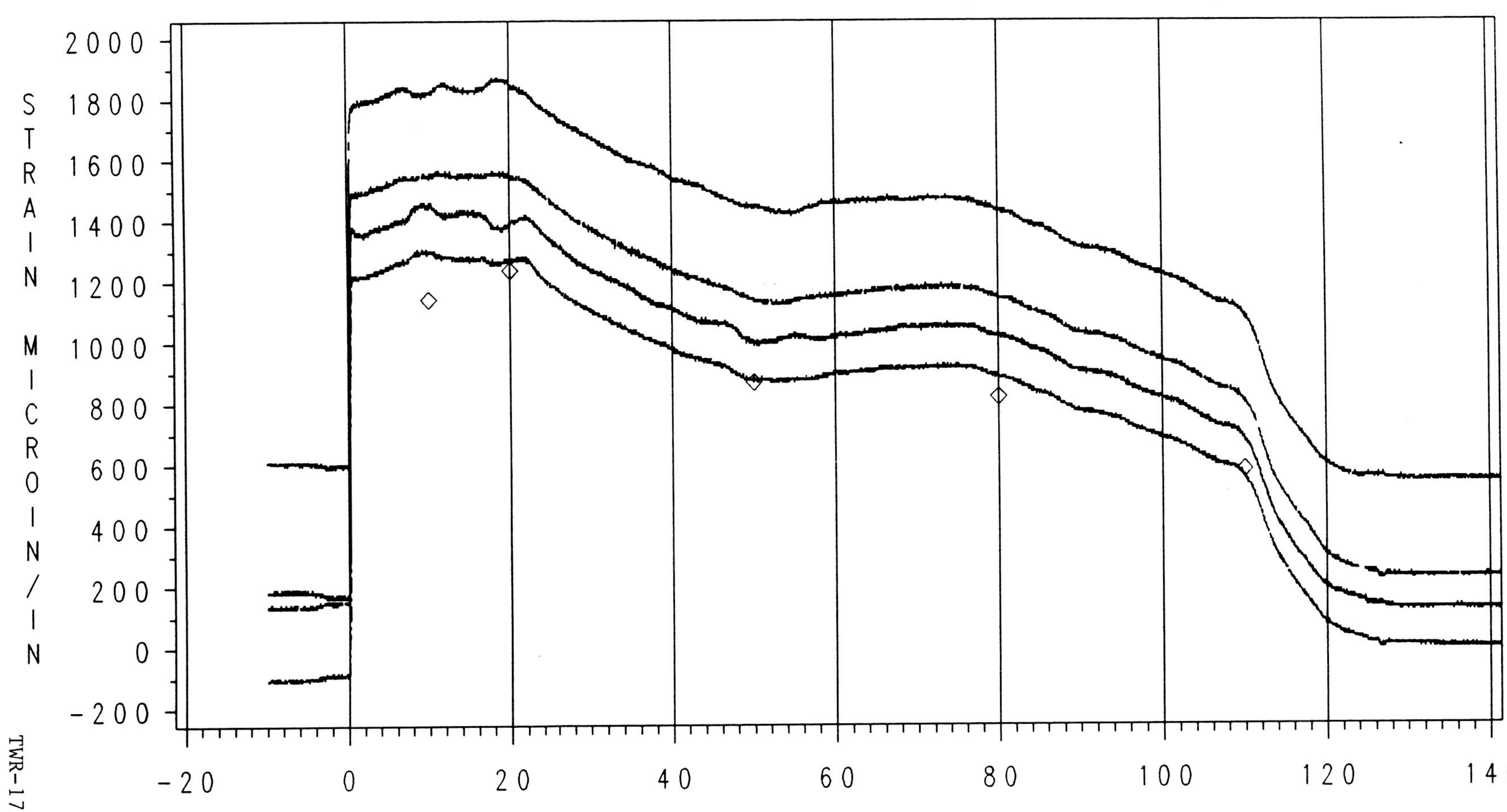
Figure 4.149 Fixed Housing (Aft End) Right

SOLID LINE=G8428A • 270 DEG

SYMBOL = PREDICTED DATA

FIXED HSG (AFT END)– LEFT

STS27 HOOP STRAINS - LOCATION 1



SOLID LINE=G7413A • 0 DEG
DASHED LINE=G7418A • 90 DEG
DOT-DASHED LINE=G7423A • 180 DEG
LONG-DASHED LINE=G7428A • 270 DEG
SYMBOL = PREDICTED DATA

Figure 4.150 Fixed Housing (Aft End) Left

FIXED HSG (AFT END)— LEFT

STS27 HOOP STRAINS - LOCATION 1

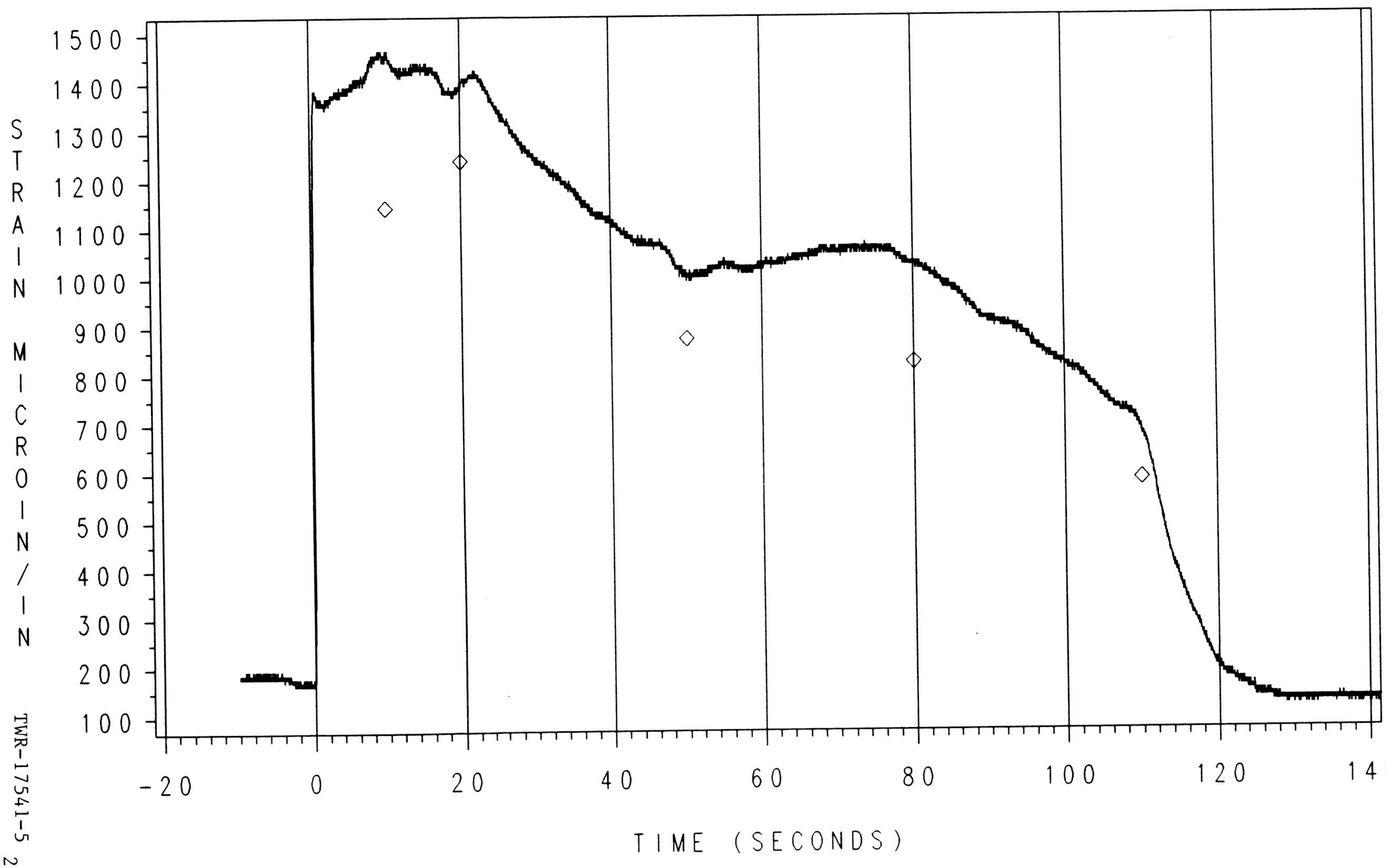


Figure 4.151 Fixed Housing (Aft End) Left

SOLID LINE=G7413A • 0 DEG

SYMBOL = PREDICTED DATA

FIXED HSG (AFT END)– LEFT

STS27 HOOP STRAINS - LOCATION 1

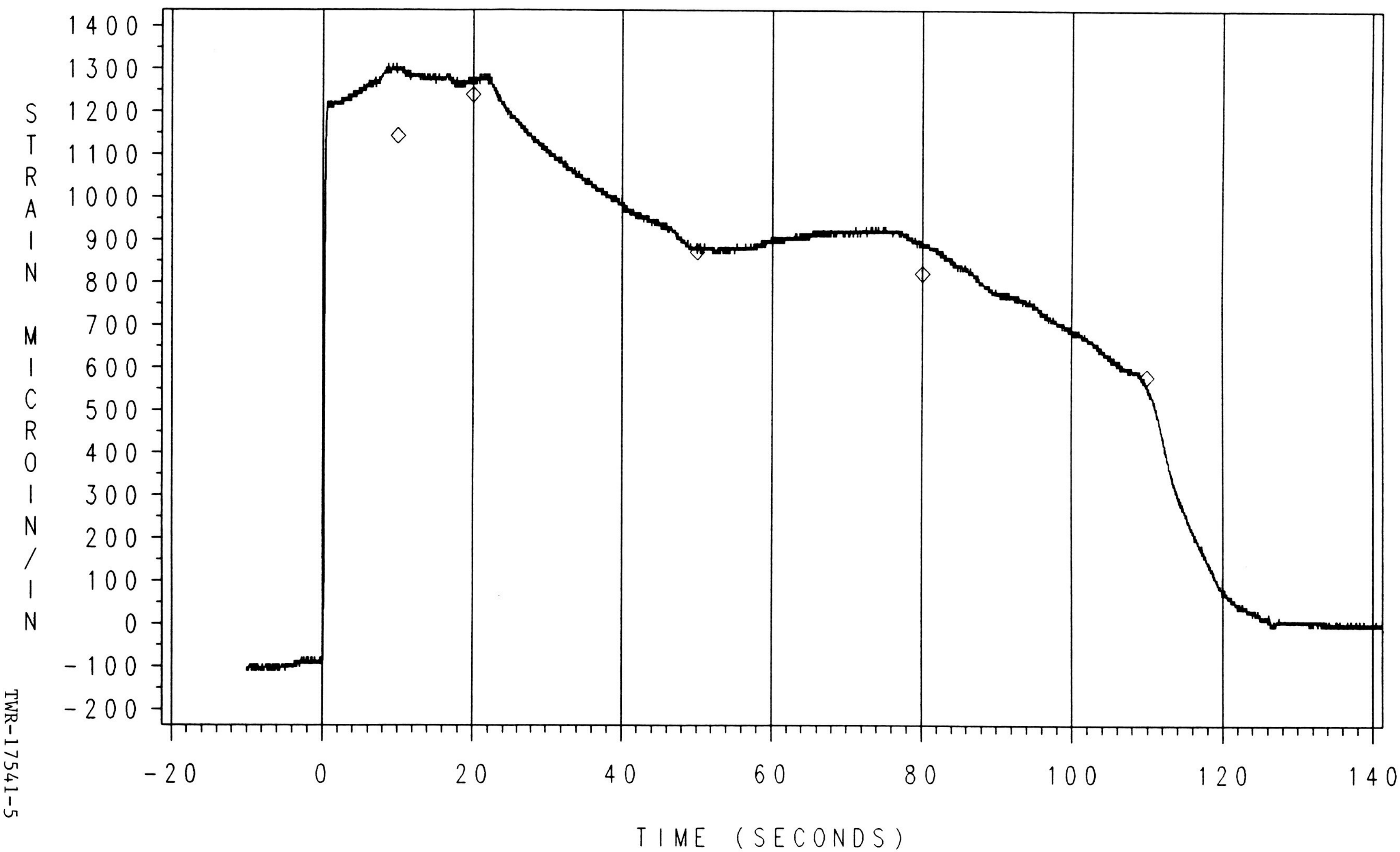


Figure 4.152 Fixed Housing (Aft End) Left

SOLID LINE=G7418A • 90 DEG

SYMBOL = PREDICTED DATA

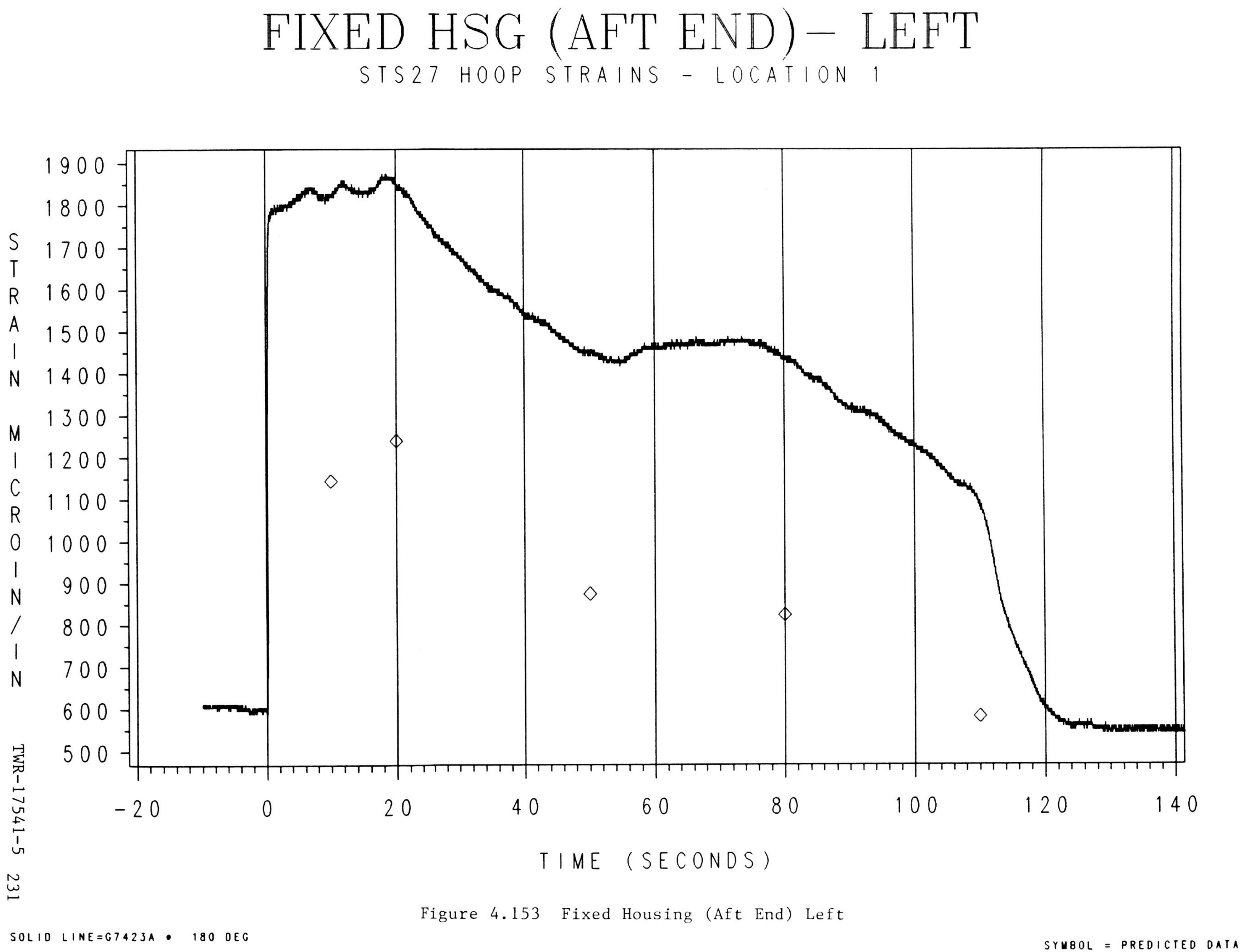


Figure 4.153 Fixed Housing (Aft End) Left

FIXED HSG (AFT END)– LEFT

STS27 HOOP STRAINS - LOCATION 1

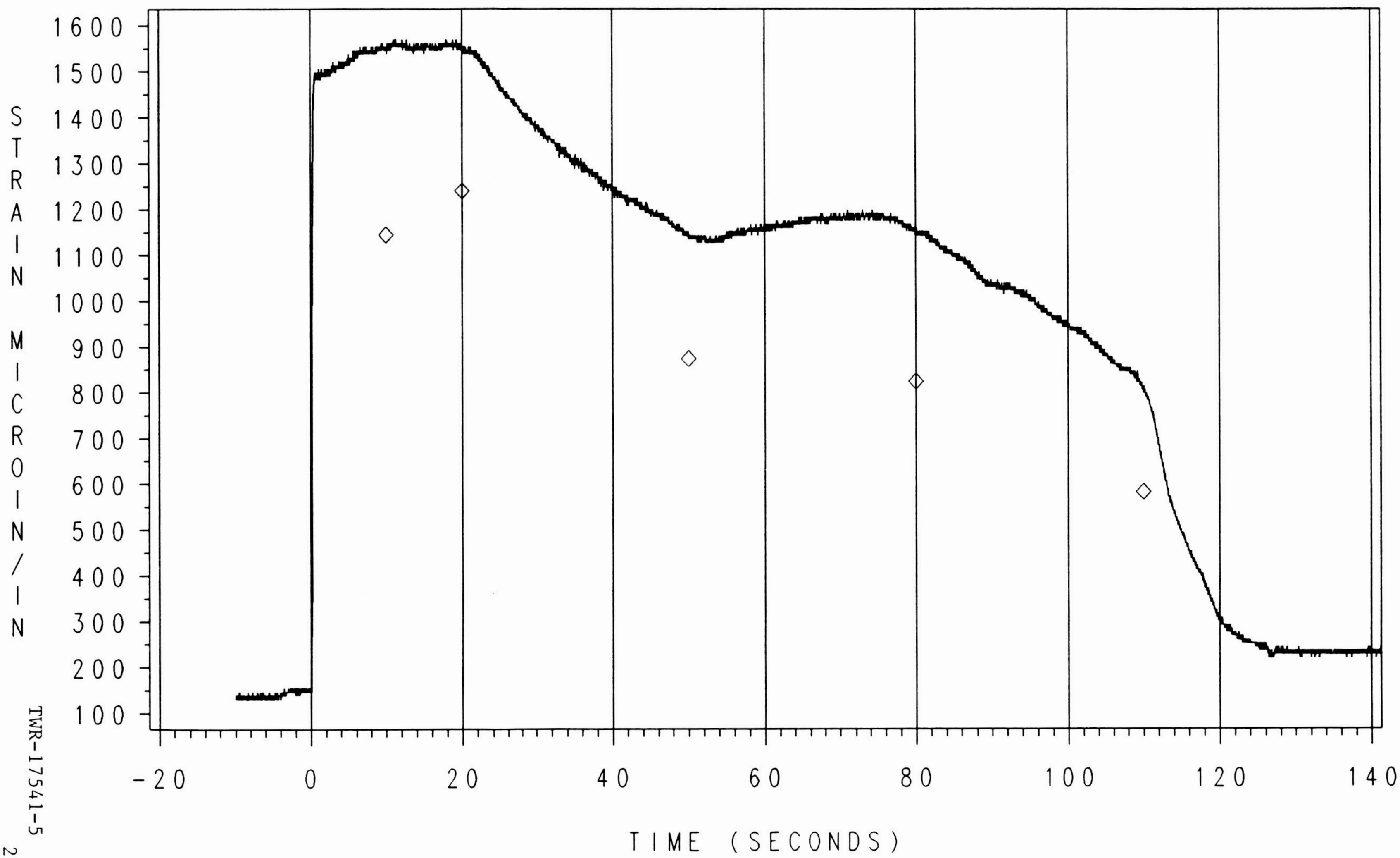


Figure 4.154 Fixed Housing (Aft End) Left

SOLID LINE=G7428A • 270 DEG

SYMBOL = PREDICTED DATA

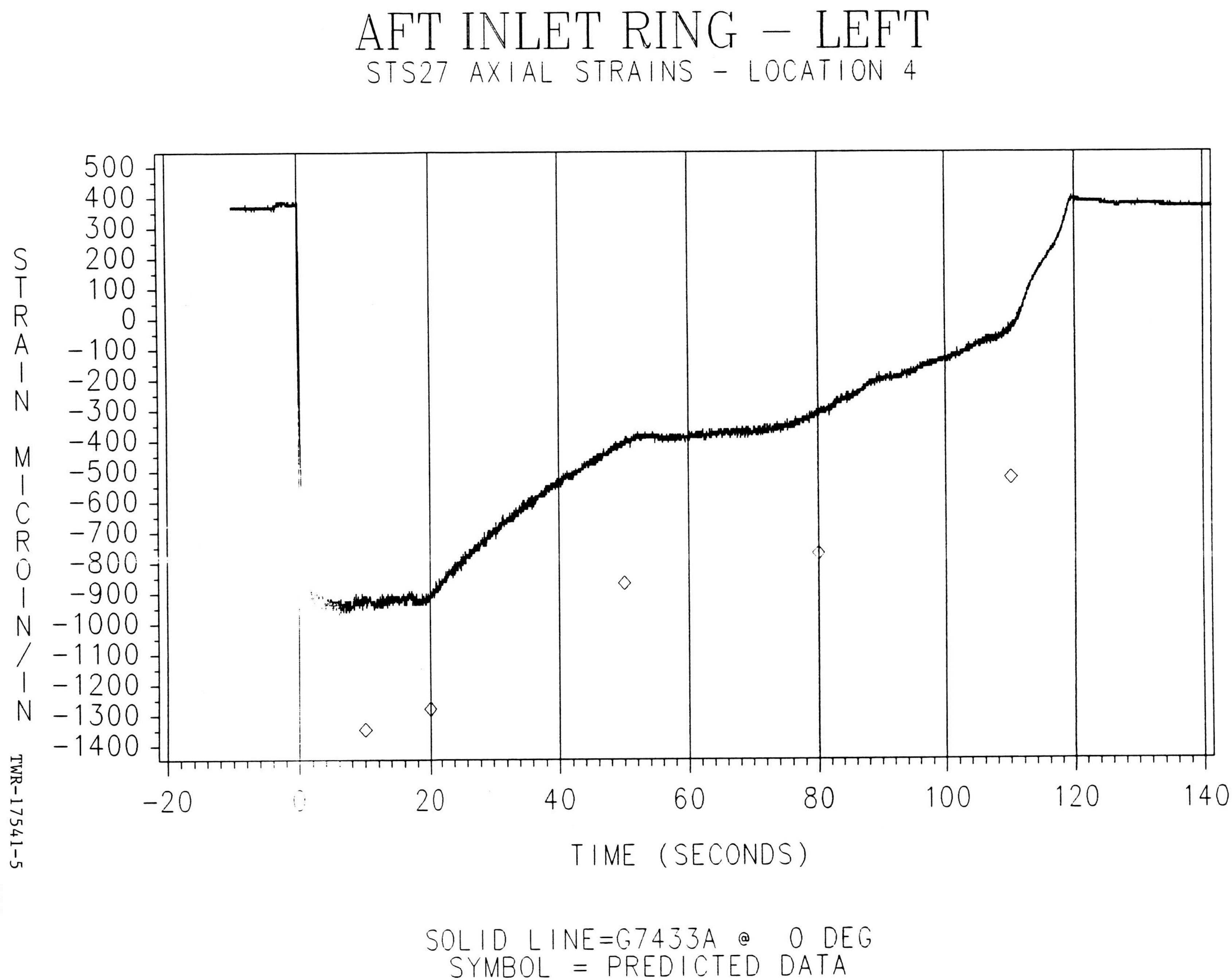


Figure 4.155 Aft Inlet Ring - Left

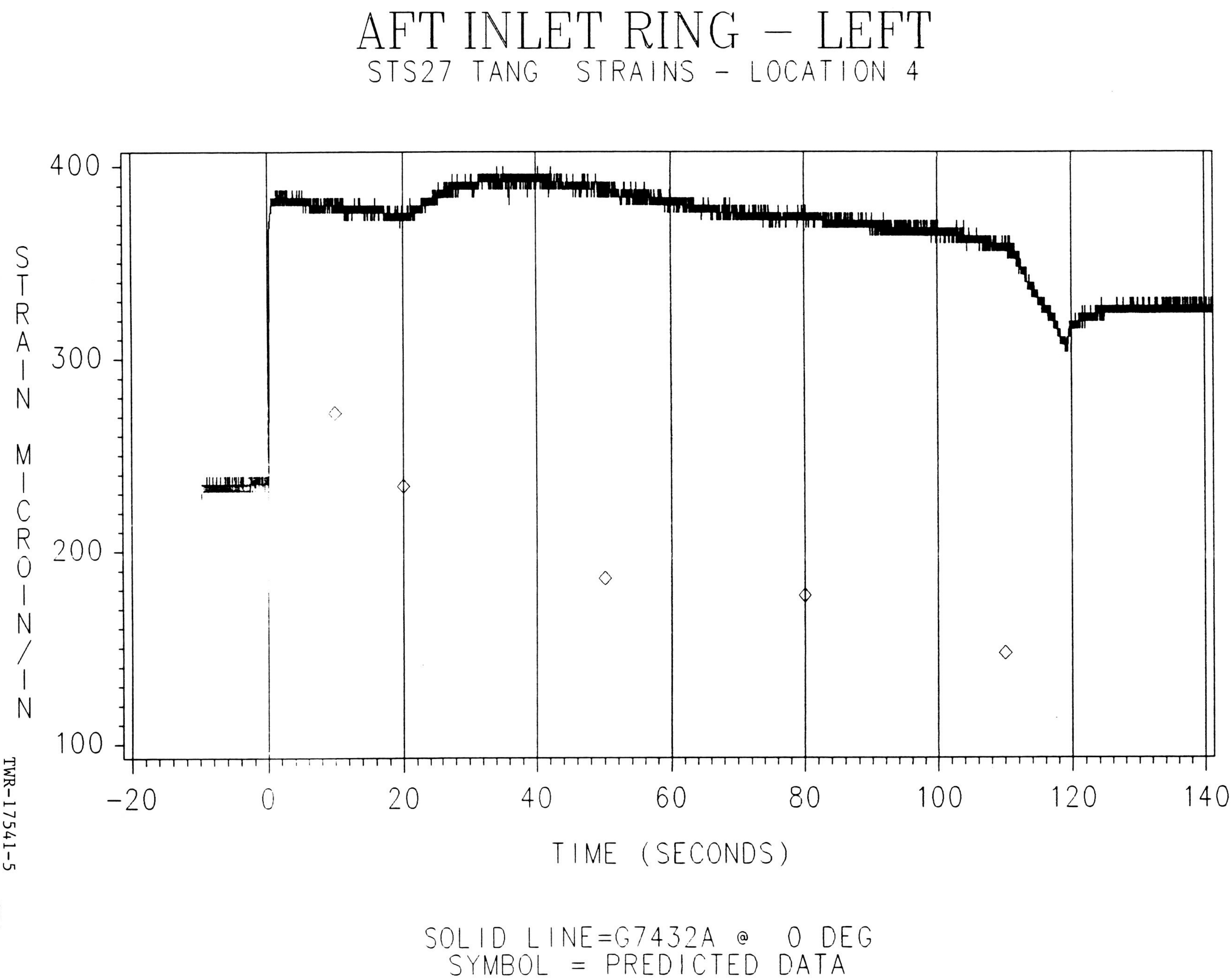


Figure 4.156 Aft Inlet Ring - Left

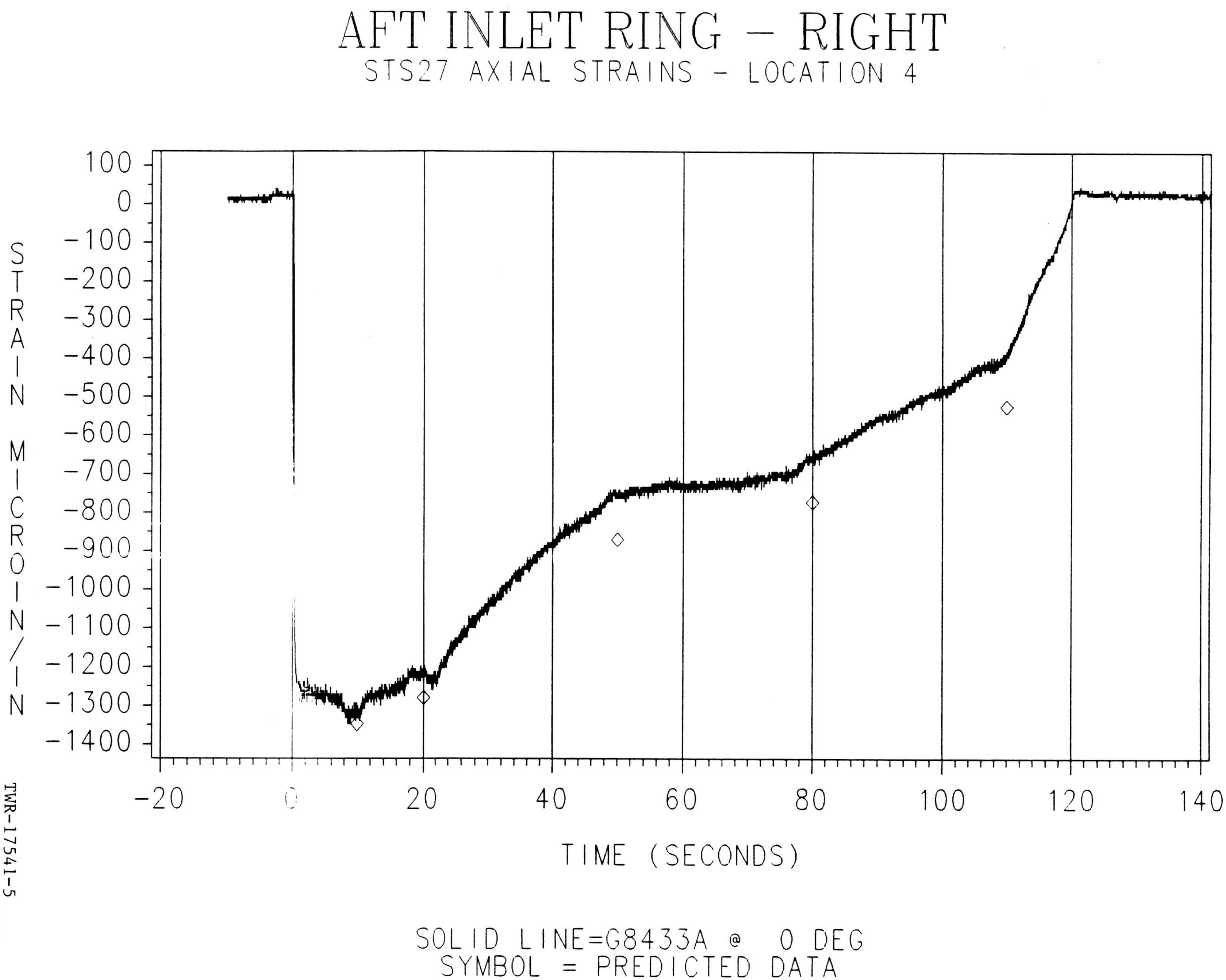


Figure 4.157 Aft Inlet Ring - Right

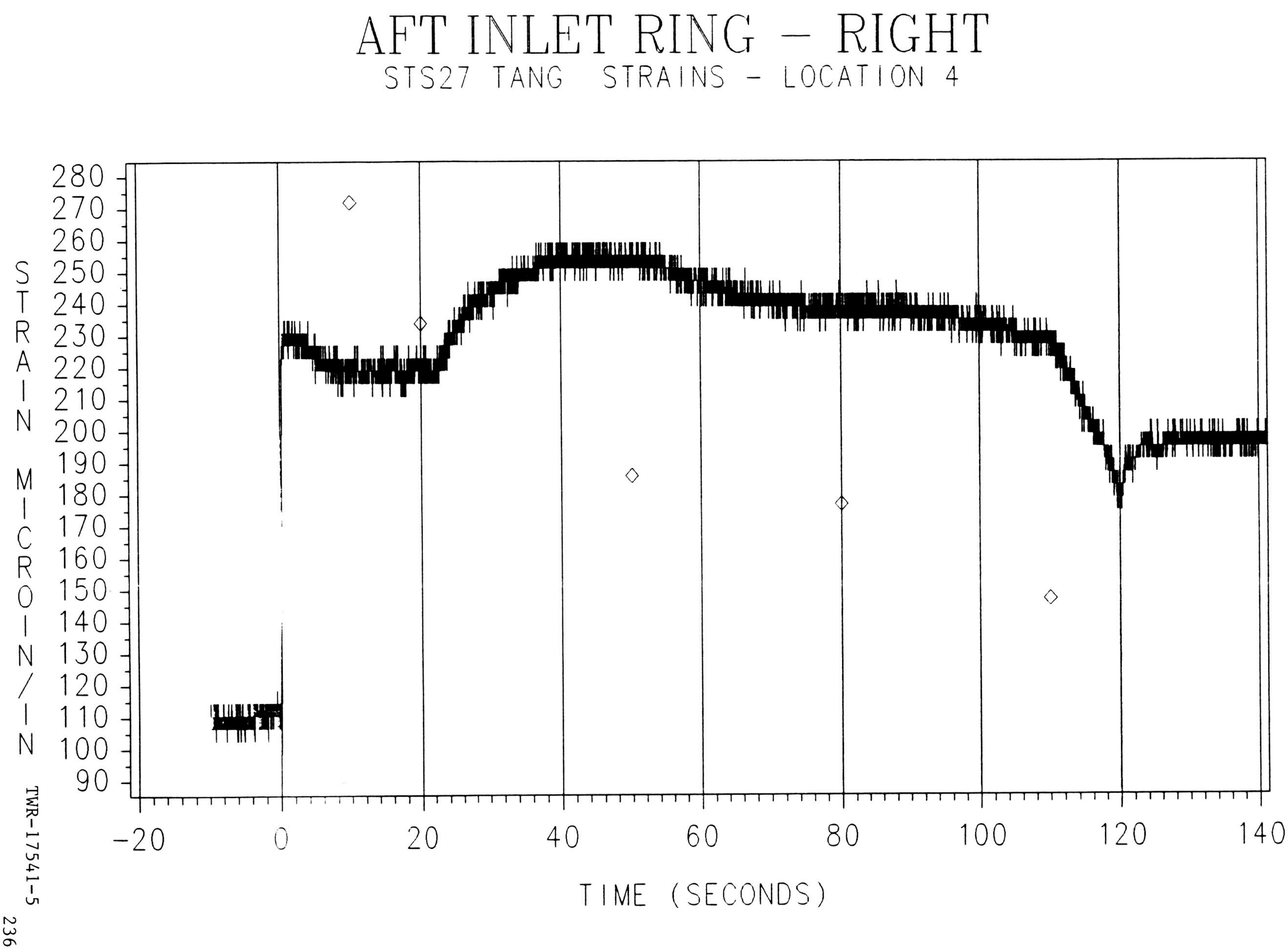


Figure 4.158 Aft Inlet Ring - Right

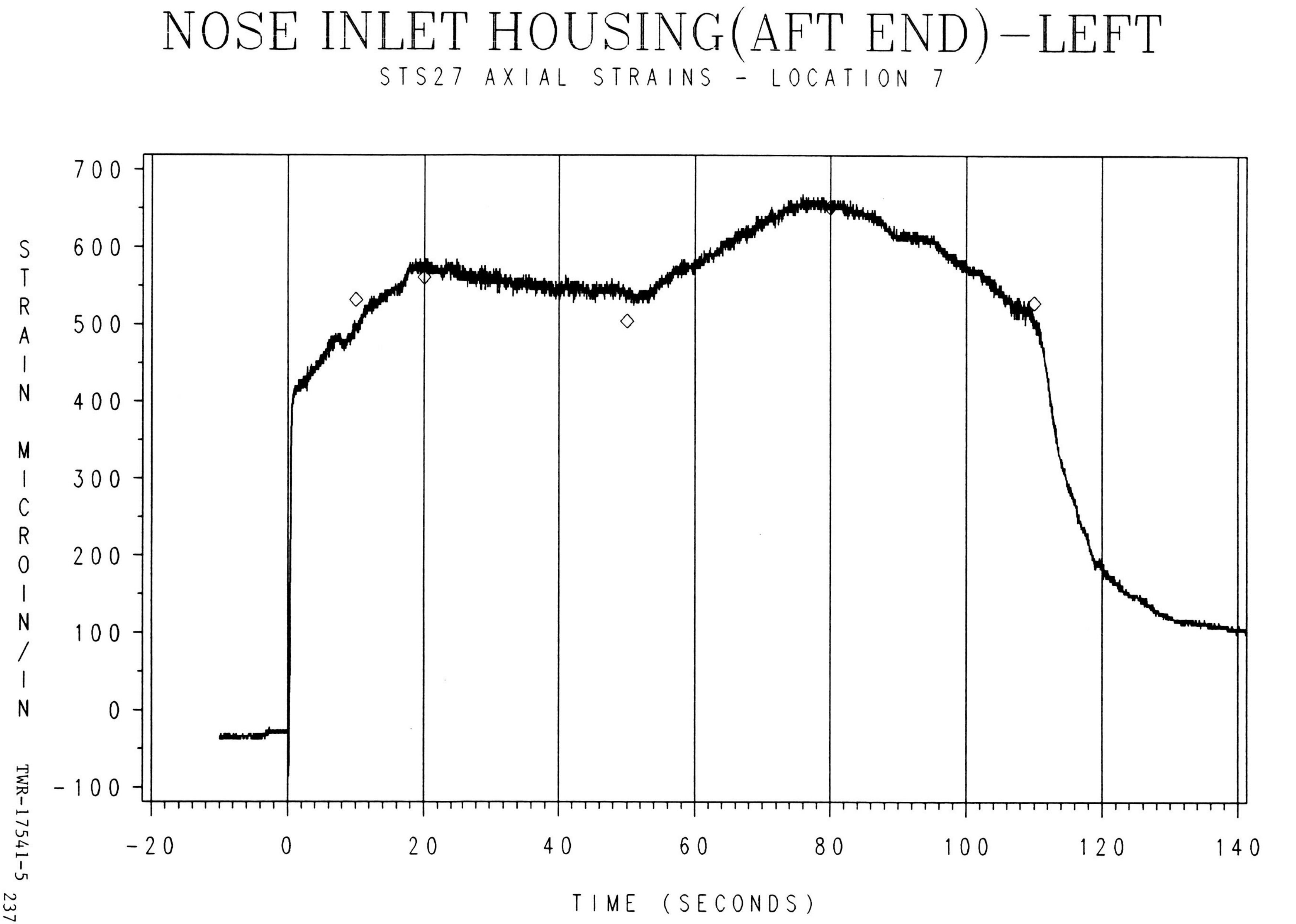


Figure 4.159 Nose Inlet Housing (Aft End) Left

SYMBOL = PREDICTED DATA

SOLID LINE=G7444A • 90 DEG

NOSE INLET HOUSING(AFT END)-LEFT

STS27 TANG STRAINS - LOCATION 7

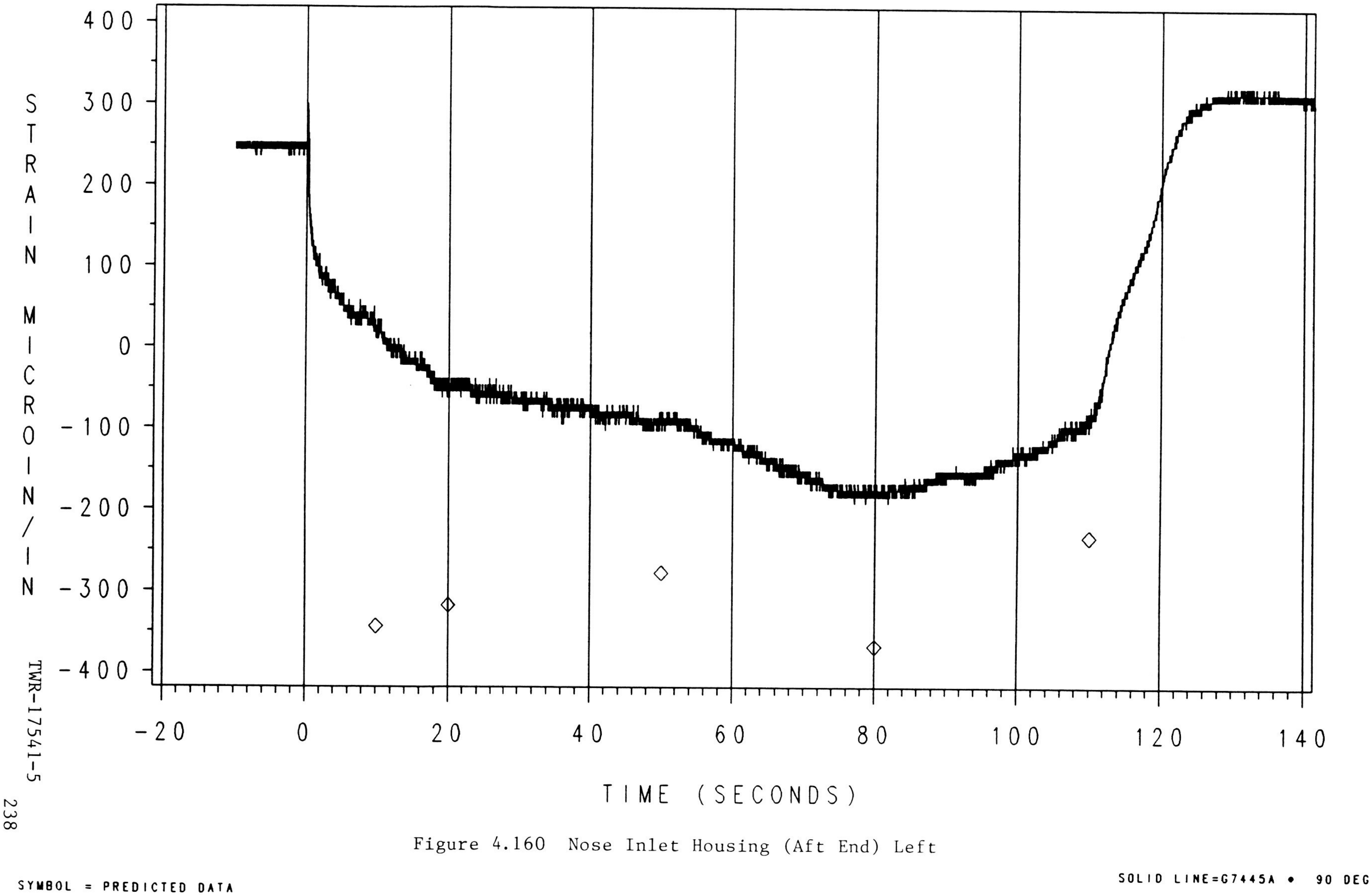


Figure 4.160 Nose Inlet Housing (Aft End) Left

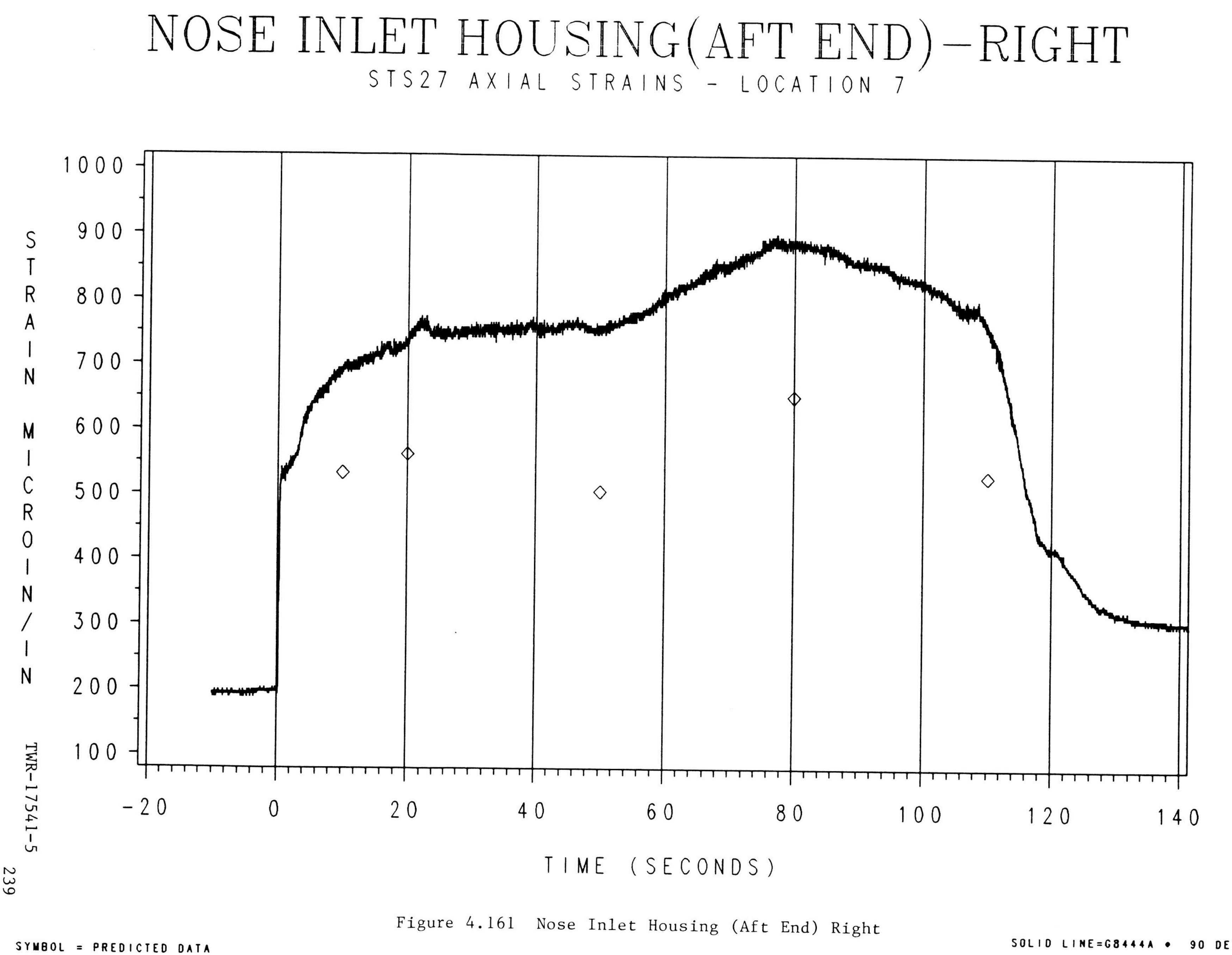


Figure 4.161 Nose Inlet Housing (Aft End) Right

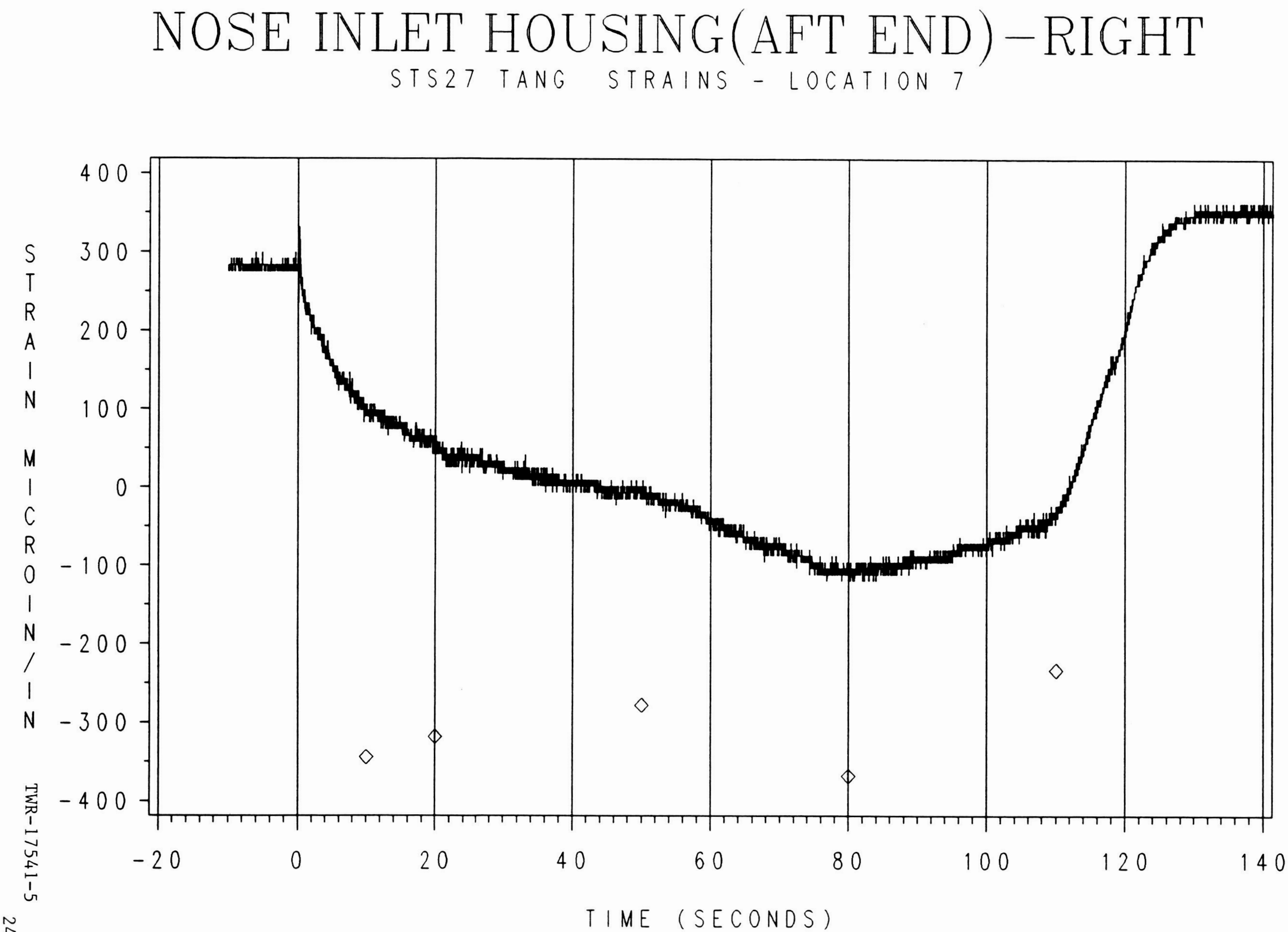


Figure 4.162 Nose Inlet Housing (Aft End) Right

SYMBOL = PREDICTED DATA

SOLID LINE=G8445A • 90 DEG

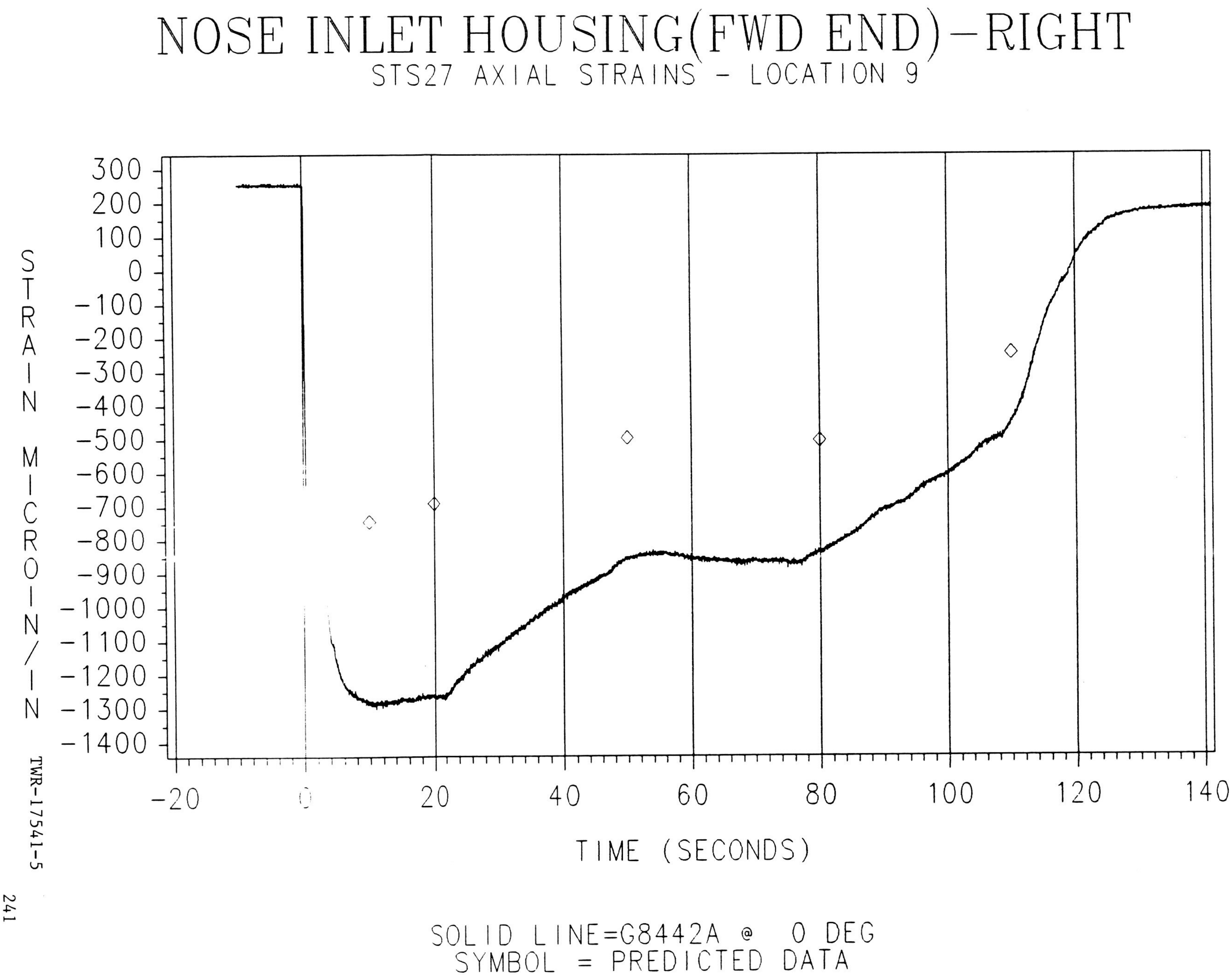


Figure 4.163 Nose Inlet Housing (Fwd End) Right

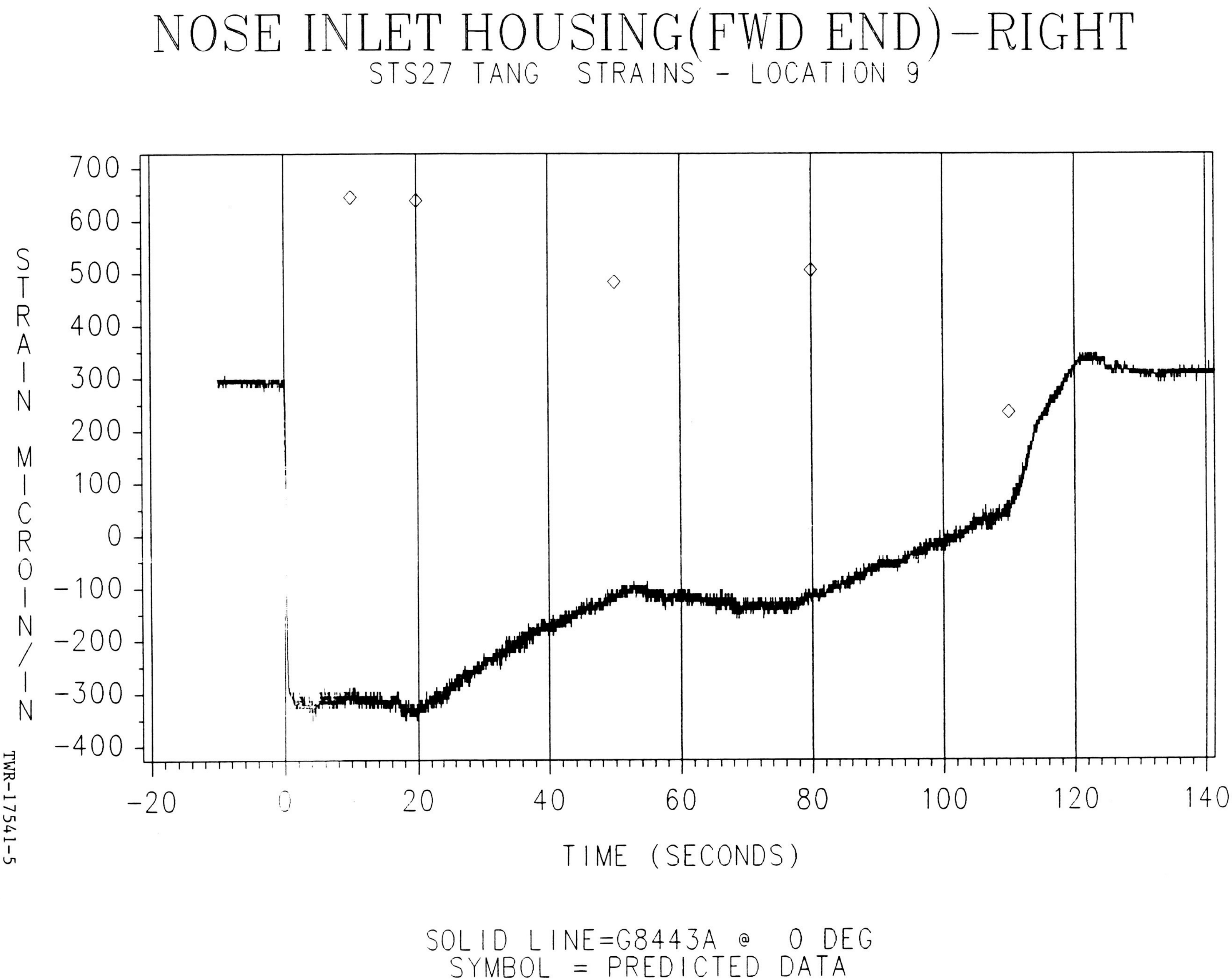


Figure 4.164 Nose Inlet Housing (Fwd End) Right

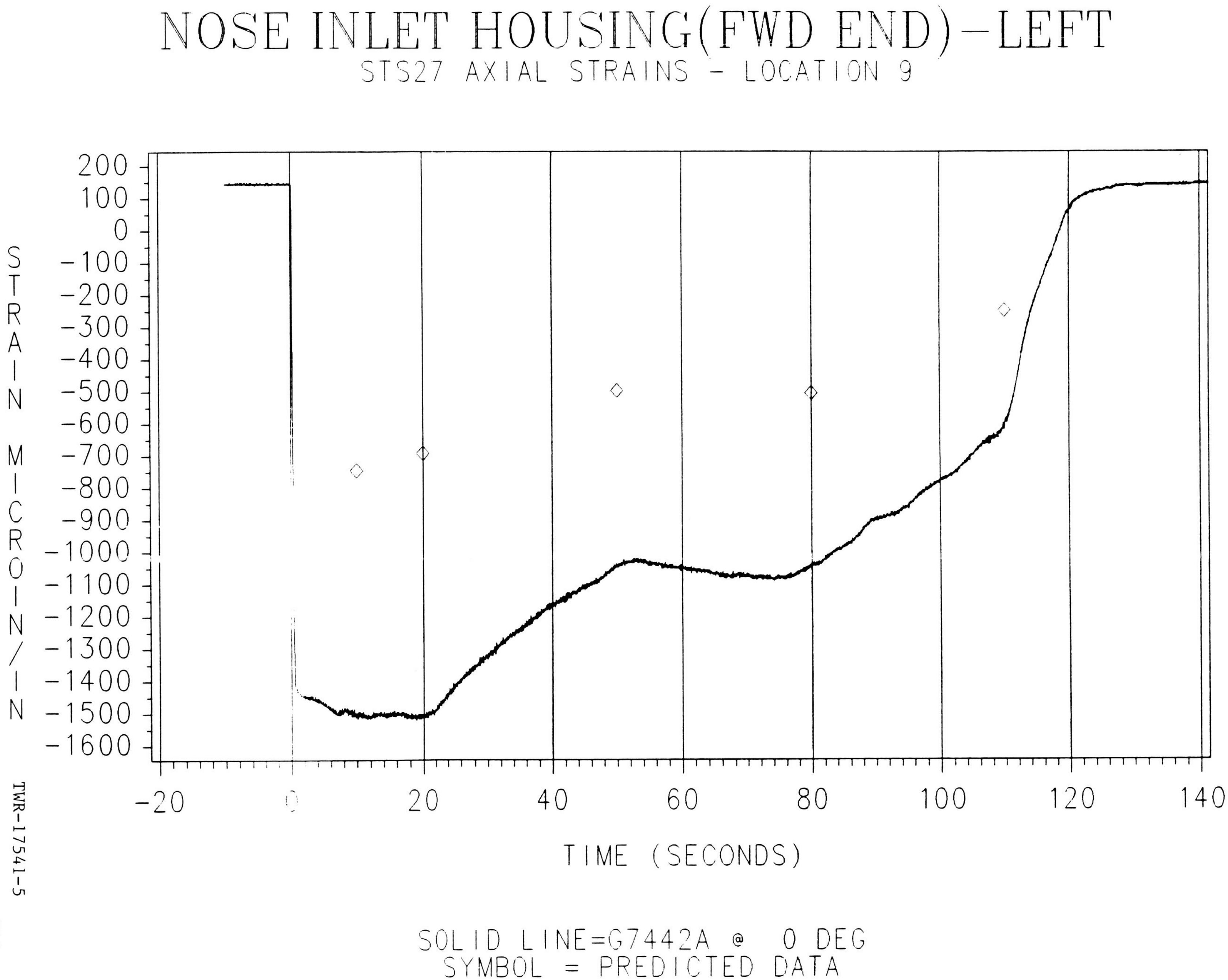


Figure 4.165 Nose Inlet Housing (Fwd End) Left

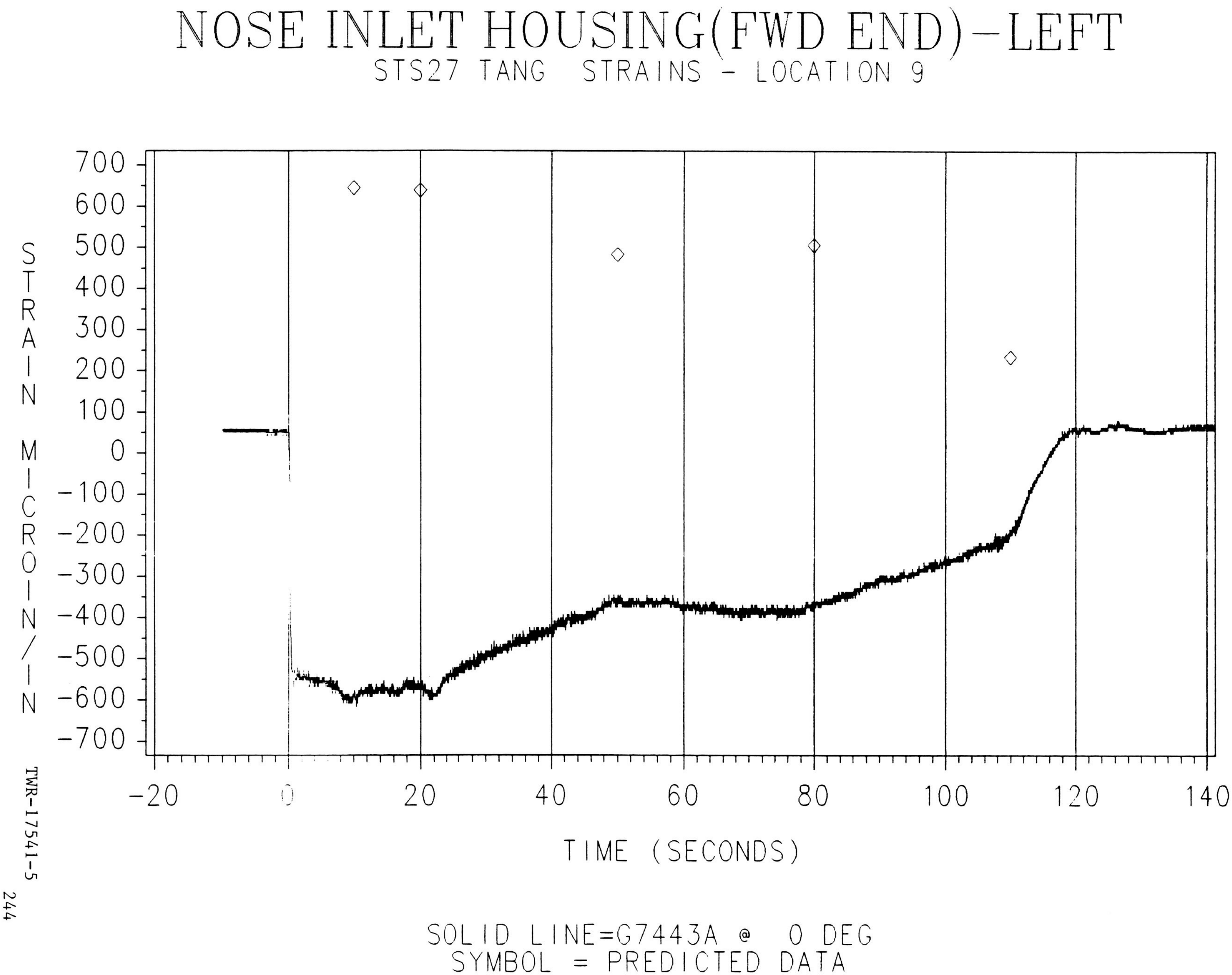
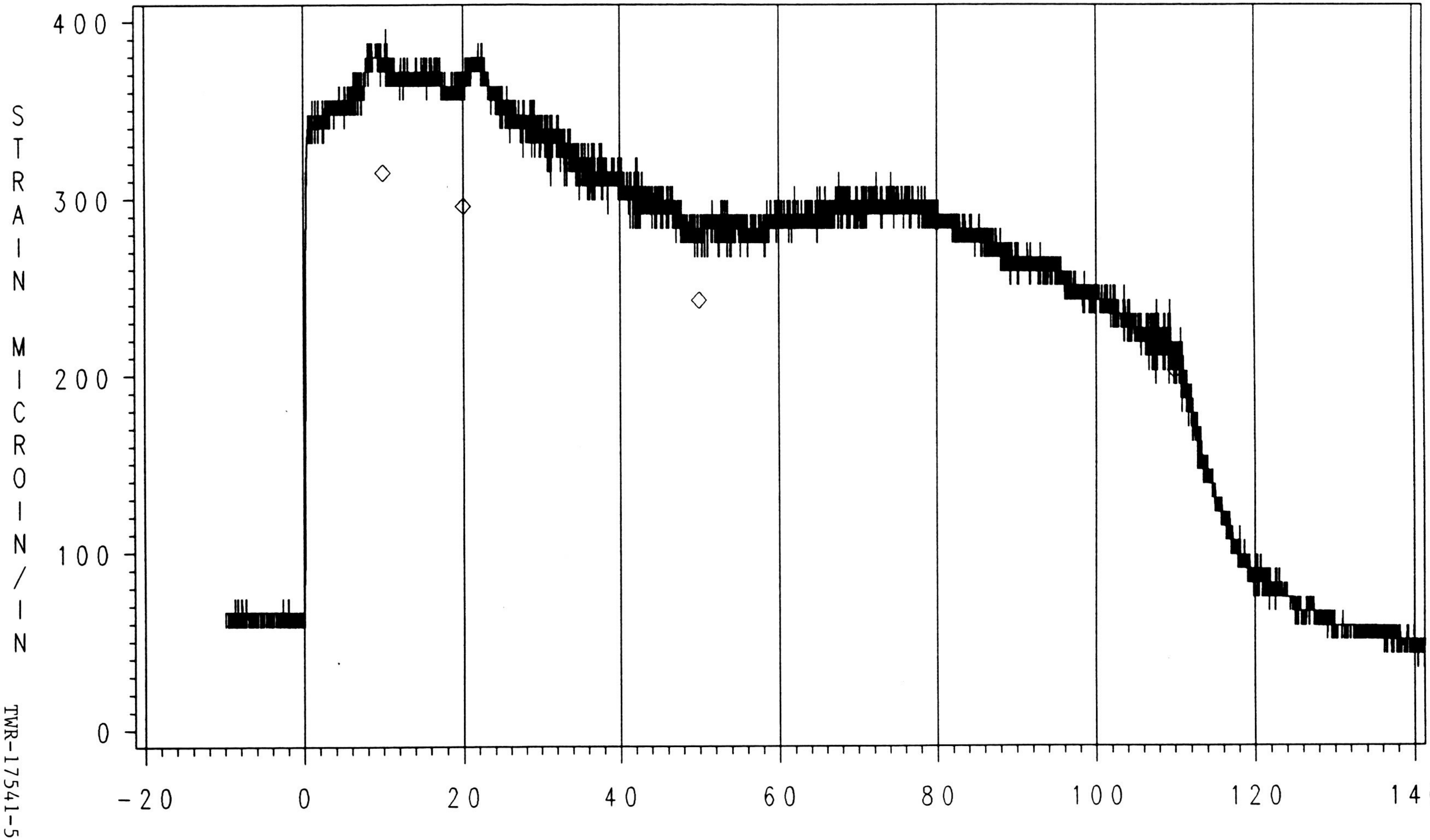


Figure 4.166 Nose Inlet Housing (Fwd End) Left

THROAT ASSEMBLY (AFT END)–LEFT

STS27 TANG STRAINS - LOCATION 13



SYMBOL = PREDICTED DATA

SOLID LINE=G7447A • 0 DEG

Figure 4.167 Throat Assembly (Aft End) Left

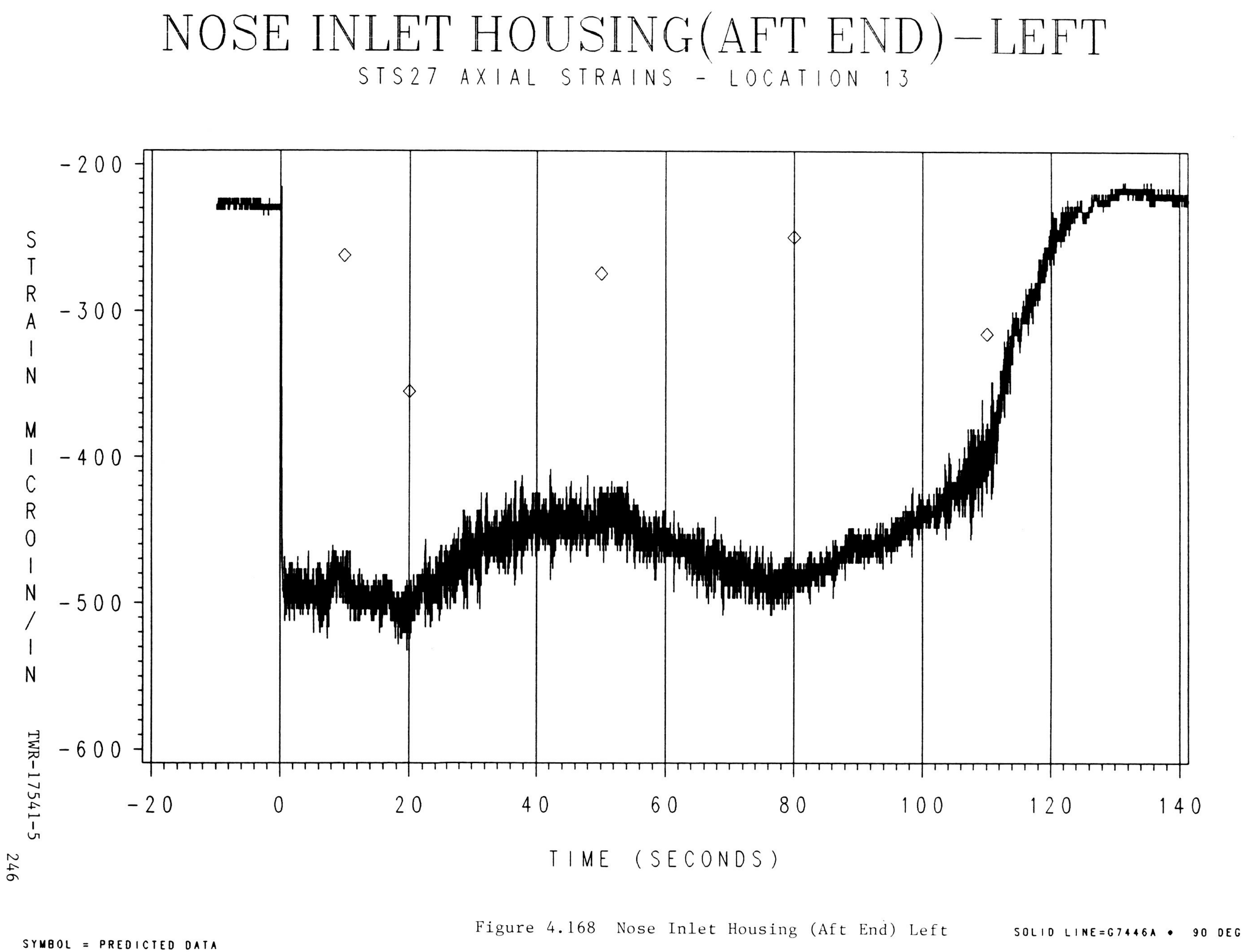


Figure 4.168 Nose Inlet Housing (Aft End) Left

THROAT ASSEMBLY(AFT END)-RIGHT

STS27 AXIAL STRAINS - LOCATION 13

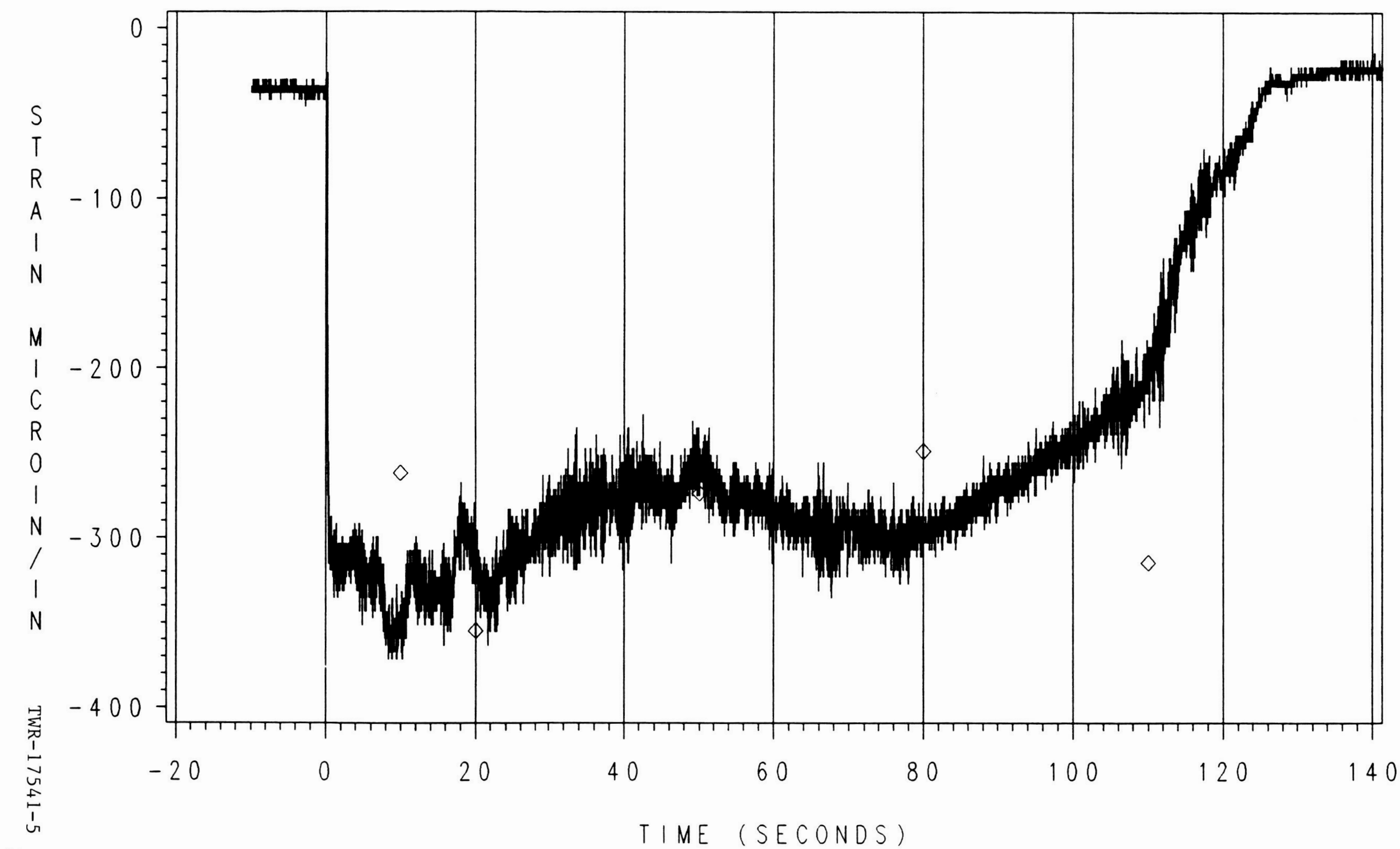


Figure 4.169 Throat Assembly (Aft End) Right

SYMBOL = PREDICTED DATA

SOLID LINE=G8446A • 90 DEG

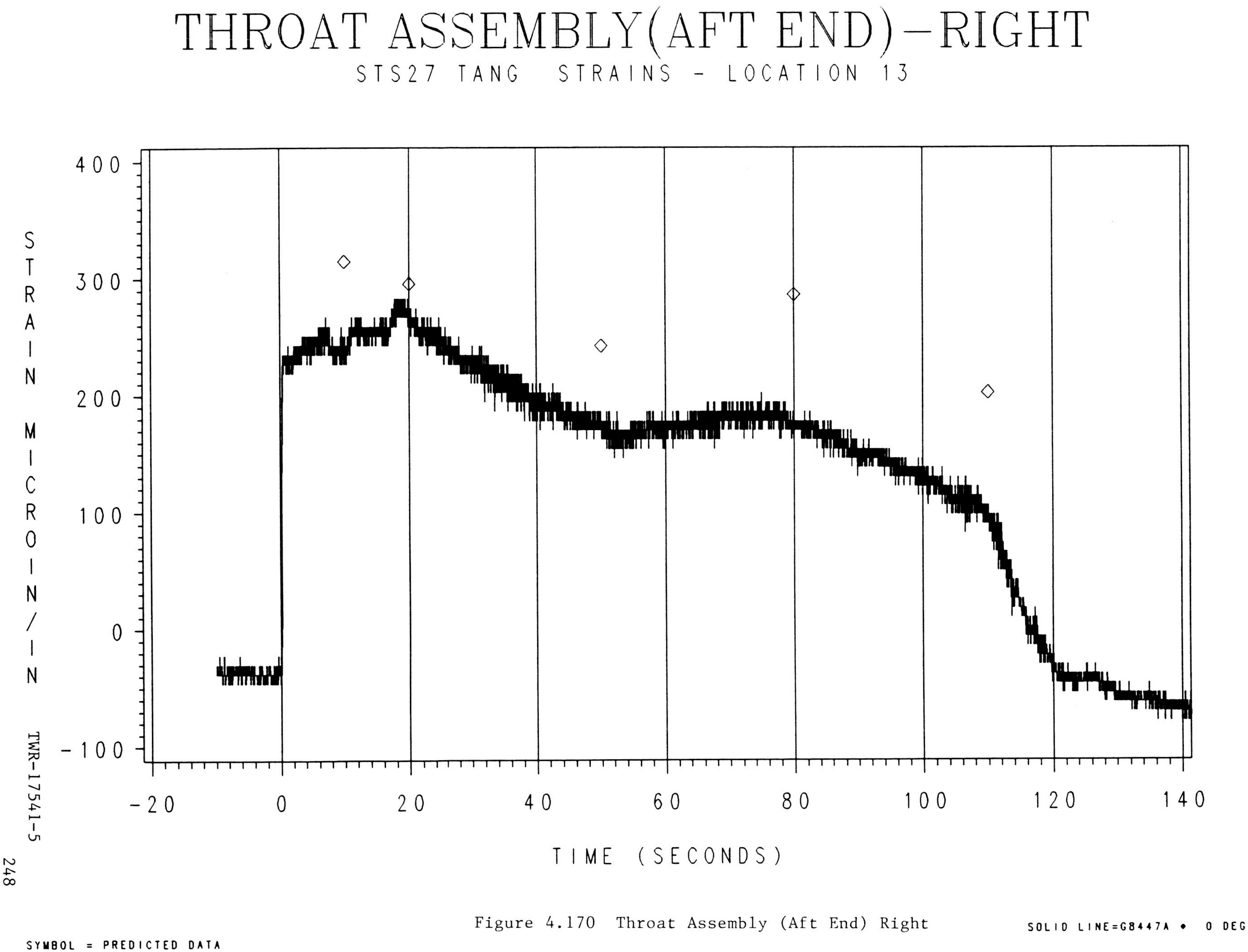


Figure 4.170 Throat Assembly (Aft End) Right

TWR-17541-5

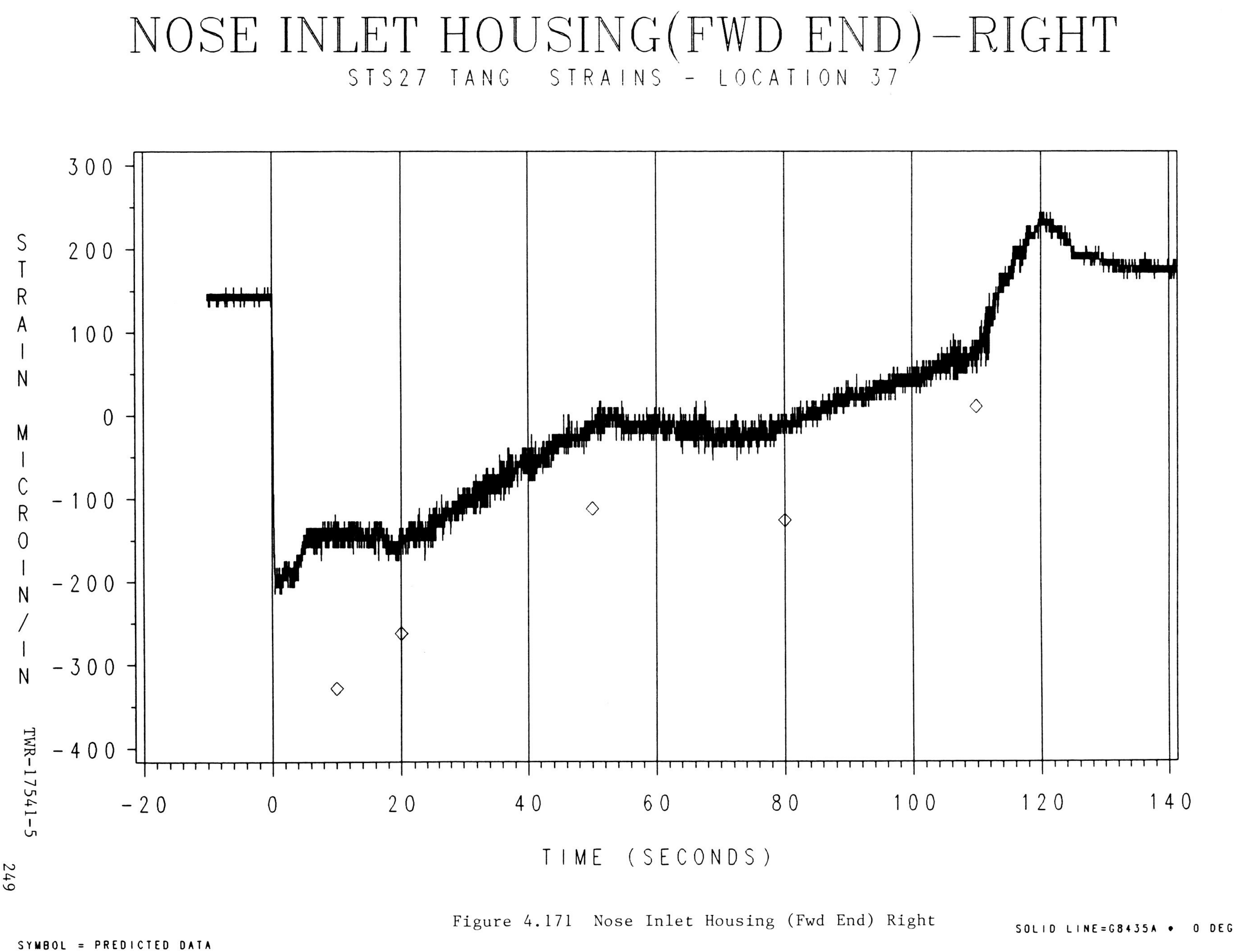
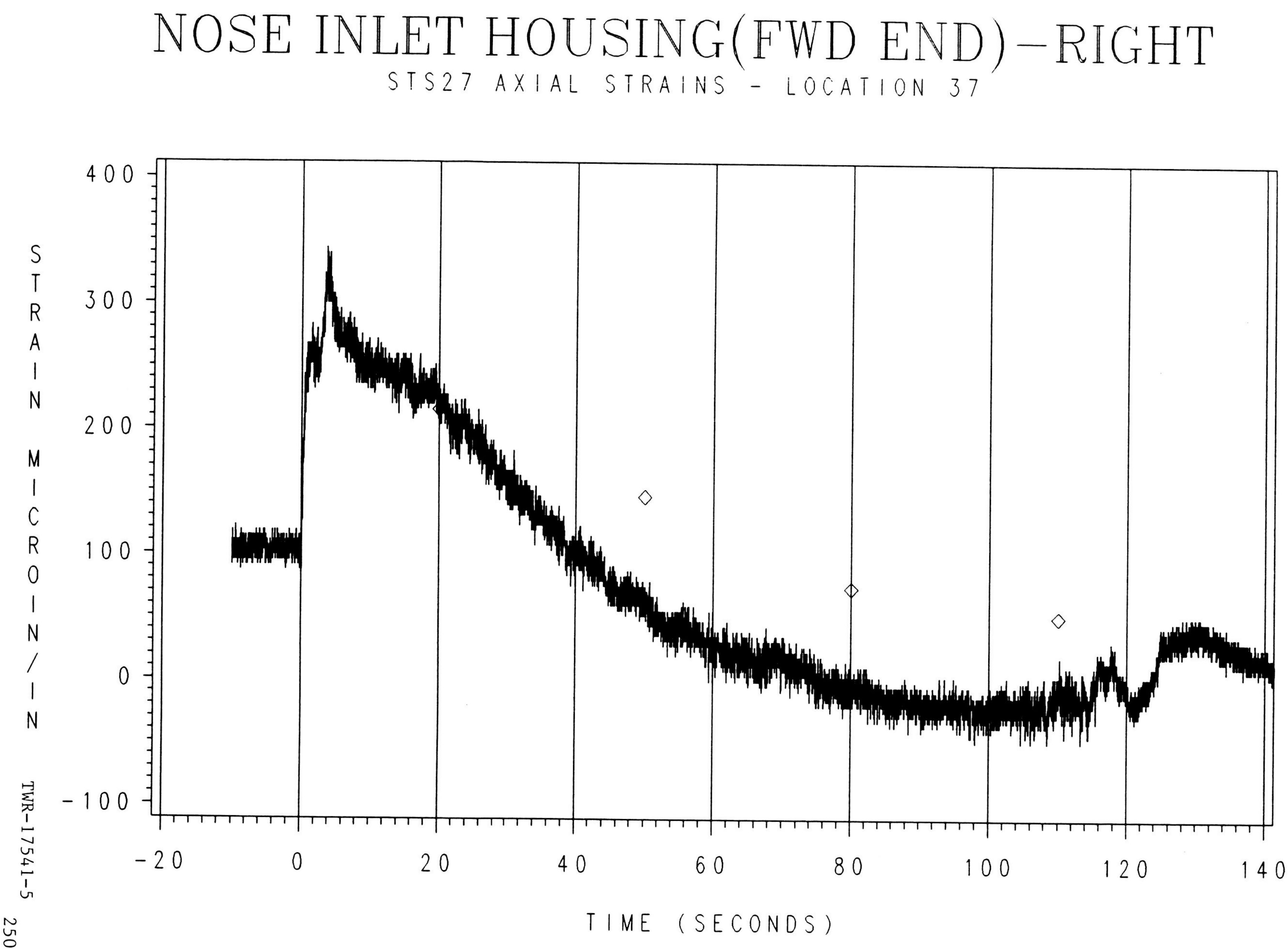


Figure 4.171 Nose Inlet Housing (Fwd End) Right



SYMBOL = PREDICTED DATA

Figure 4.172 Nose Inlet Housing (Fwd End) Right

SOLID LINE=G8434A • 0 DEG

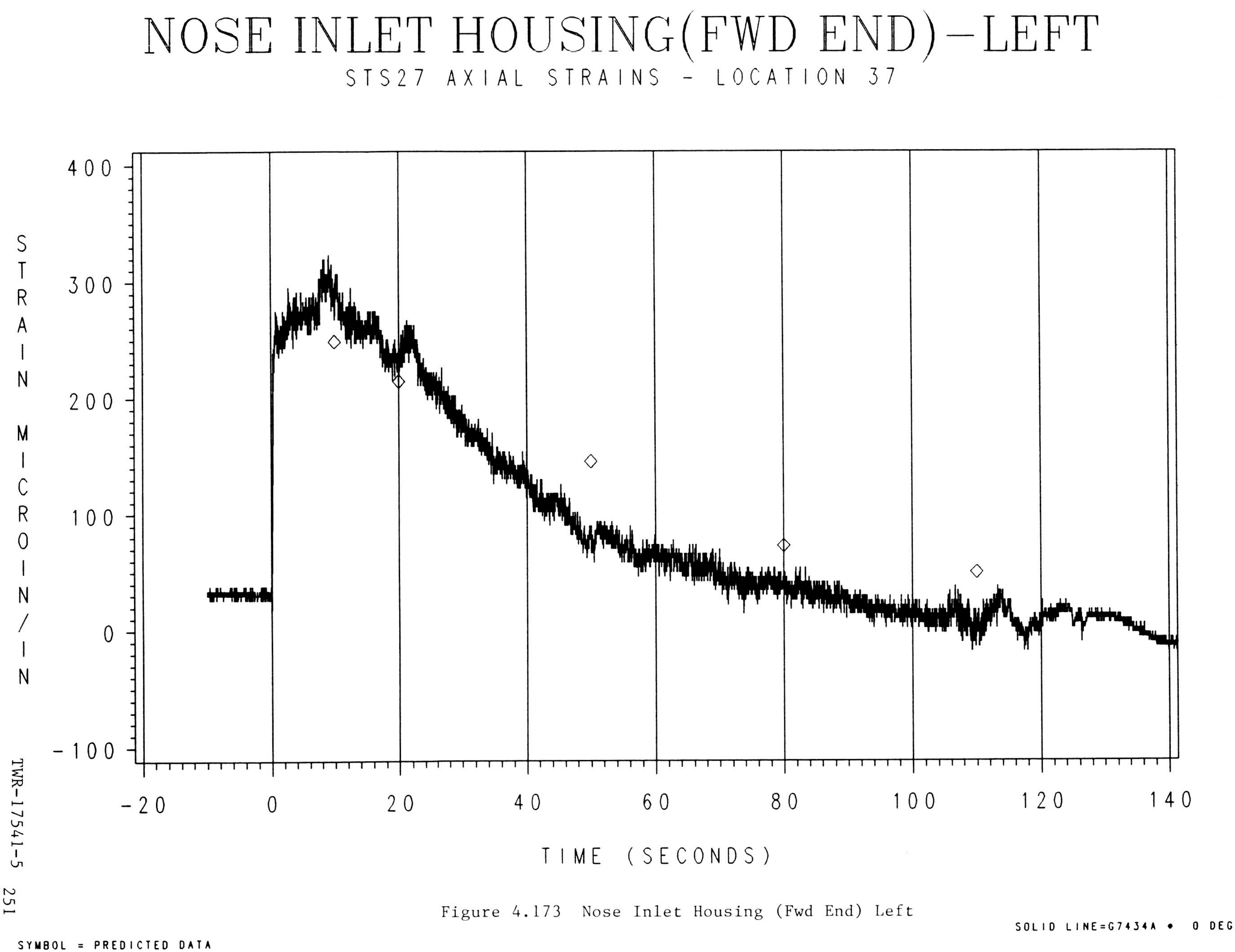


Figure 4.173 Nose Inlet Housing (Fwd End) Left

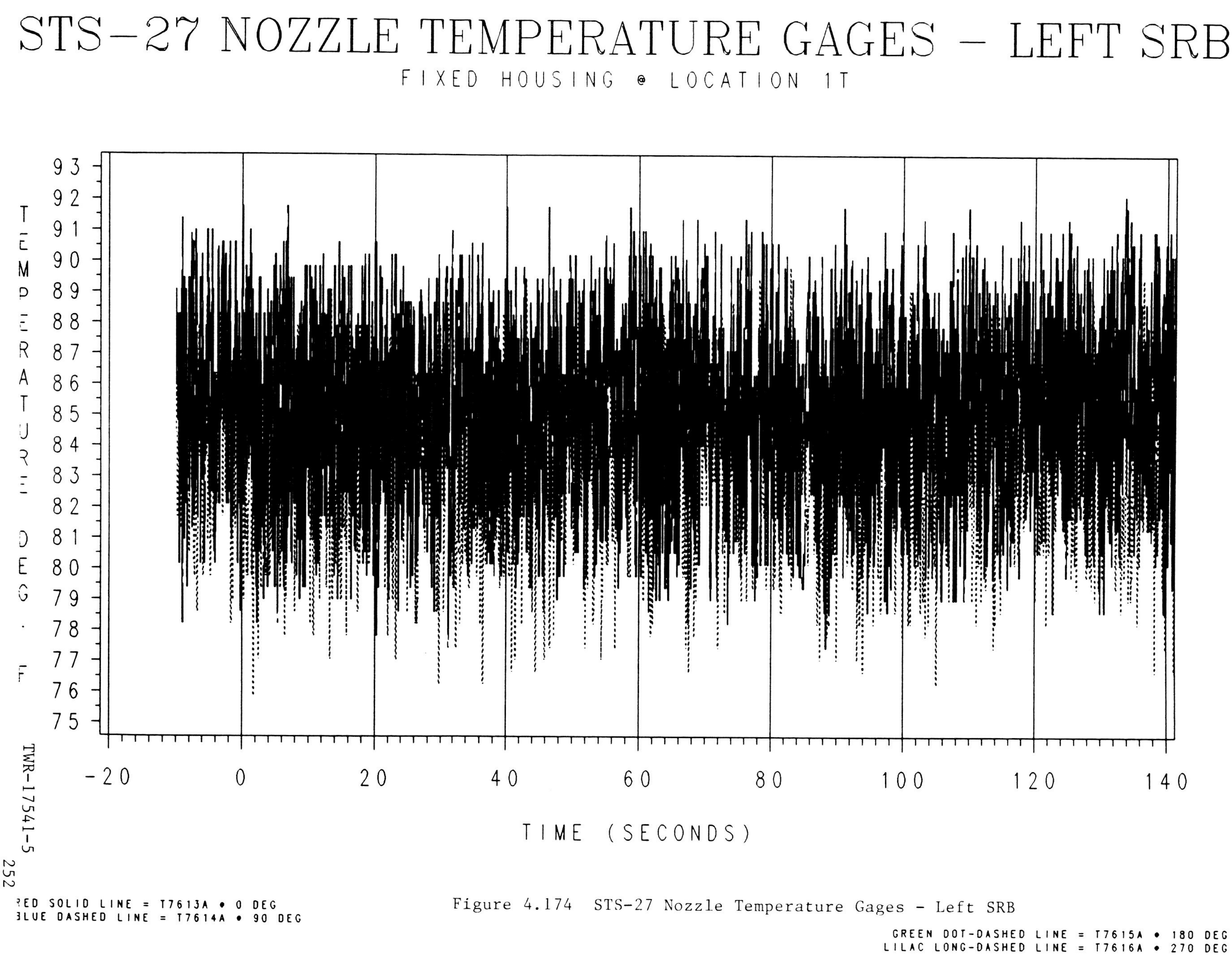


Figure 4.174 STS-27 Nozzle Temperature Gages - Left SRB

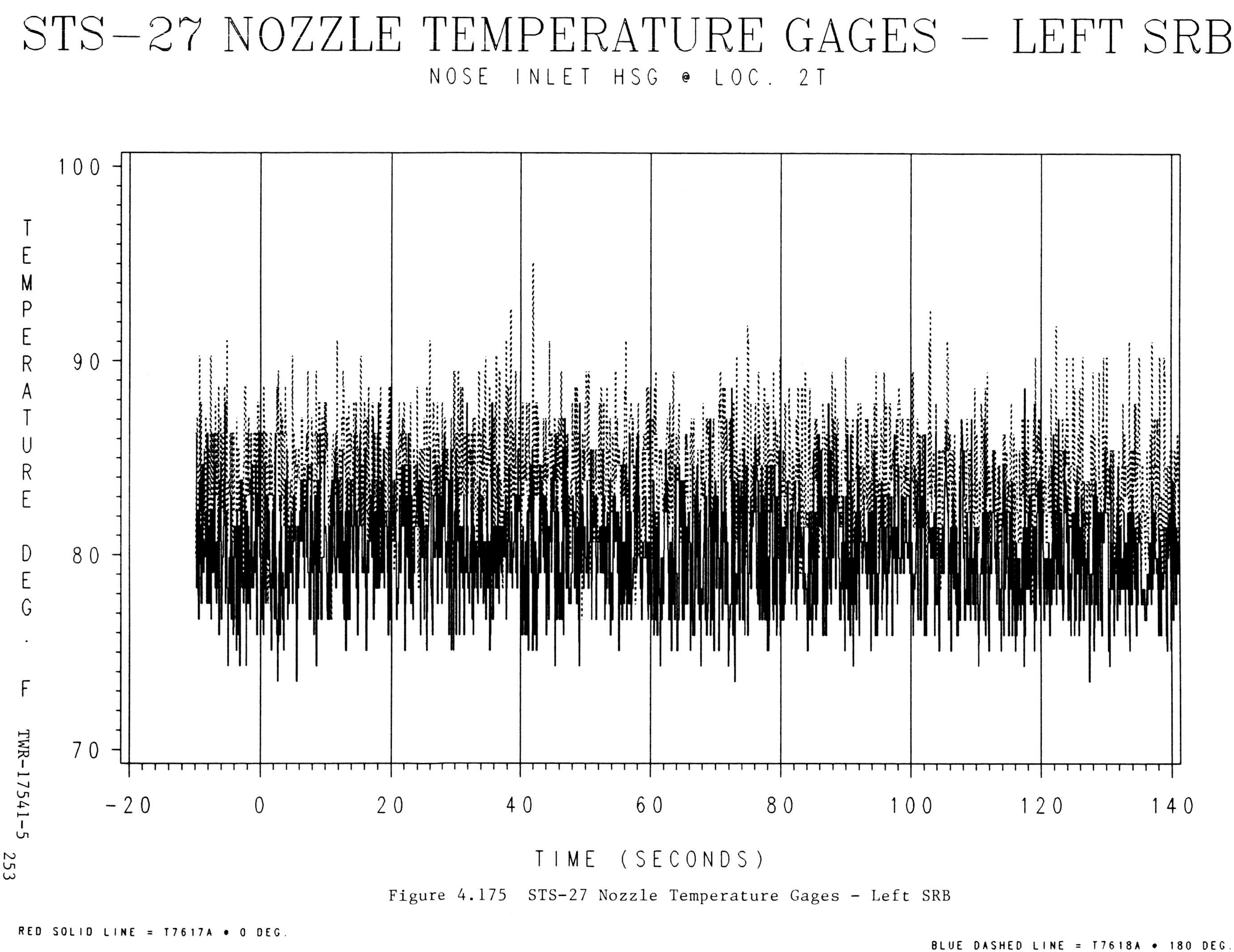


Figure 4.175 STS-27 Nozzle Temperature Gages - Left SRB

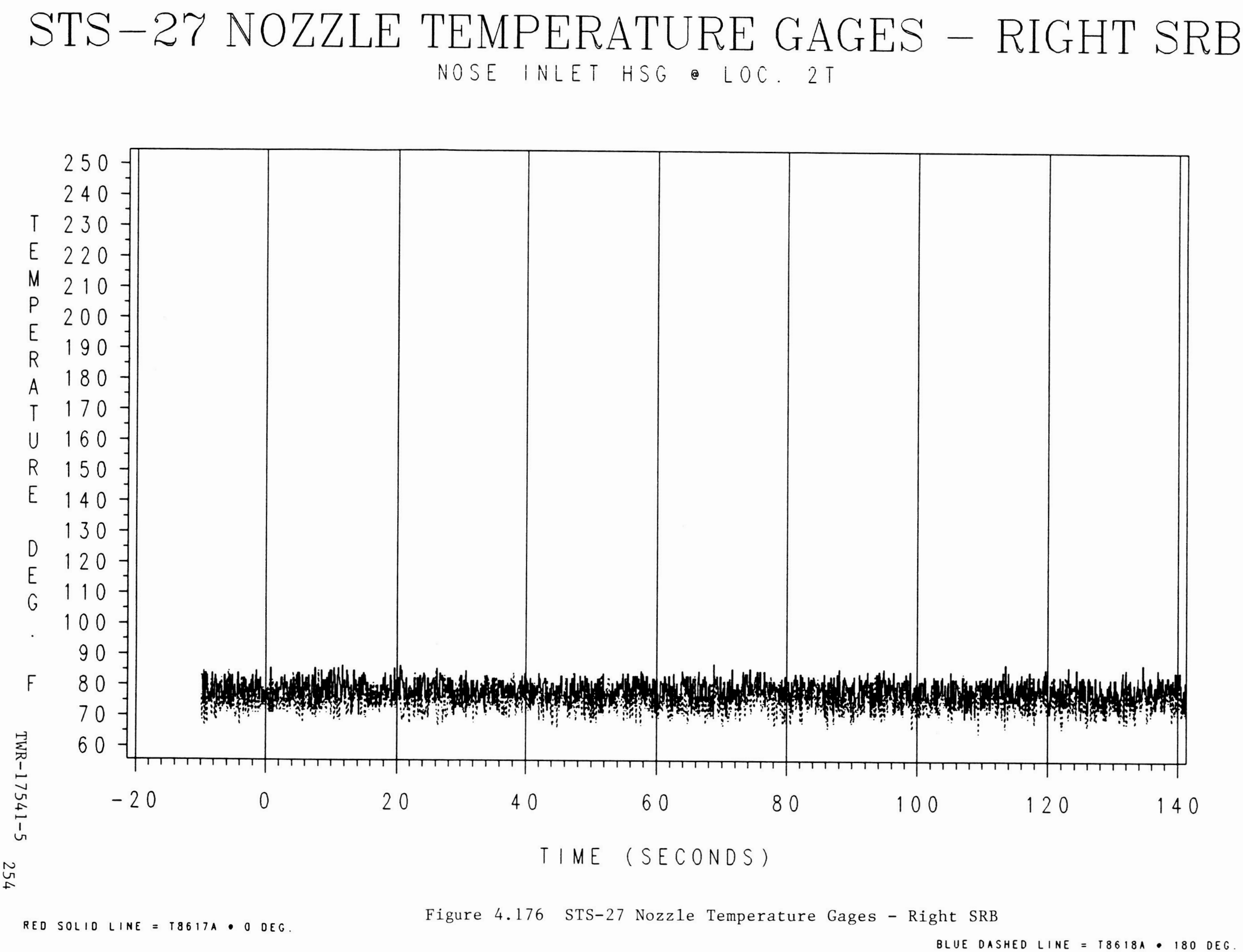
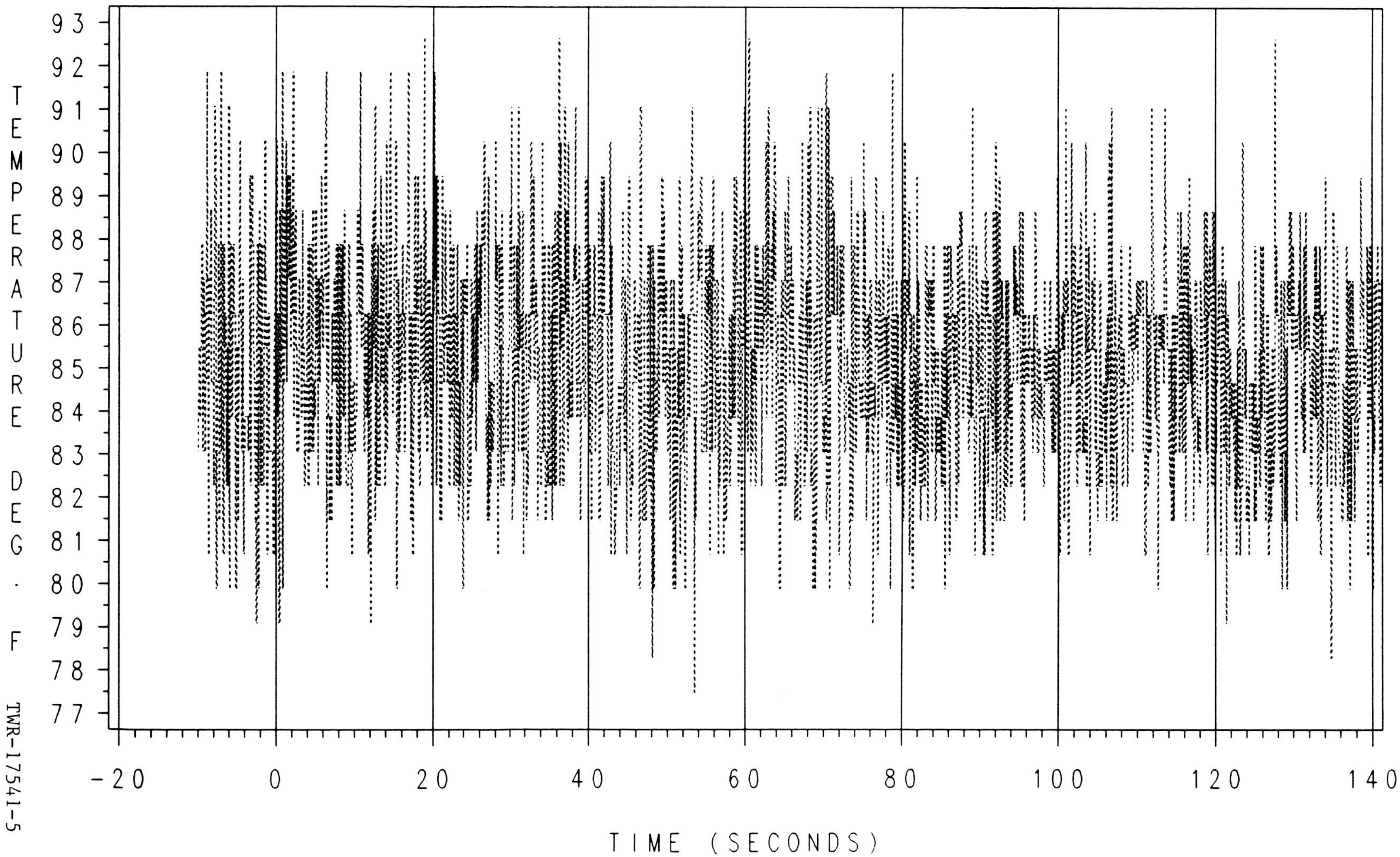


Figure 4.176 STS-27 Nozzle Temperature Gages - Right SRB

STS-27 NOZZLE TEMPERATURE GAGES - LEFT SRB

THROAT ASSY. @ LOC. 3T



RED SOLID LINE = T7620A • 90 DEG.

Figure 4.177 STS-27 Nozzle Temperature Gages - Left SRB

BLUE DASHED LINE = T7621A • 270 DEG.

STS-27 NOZZLE TEMPERATURE GAGES - RIGHT SRB

THROAT ASSY. @ LOC. 3T

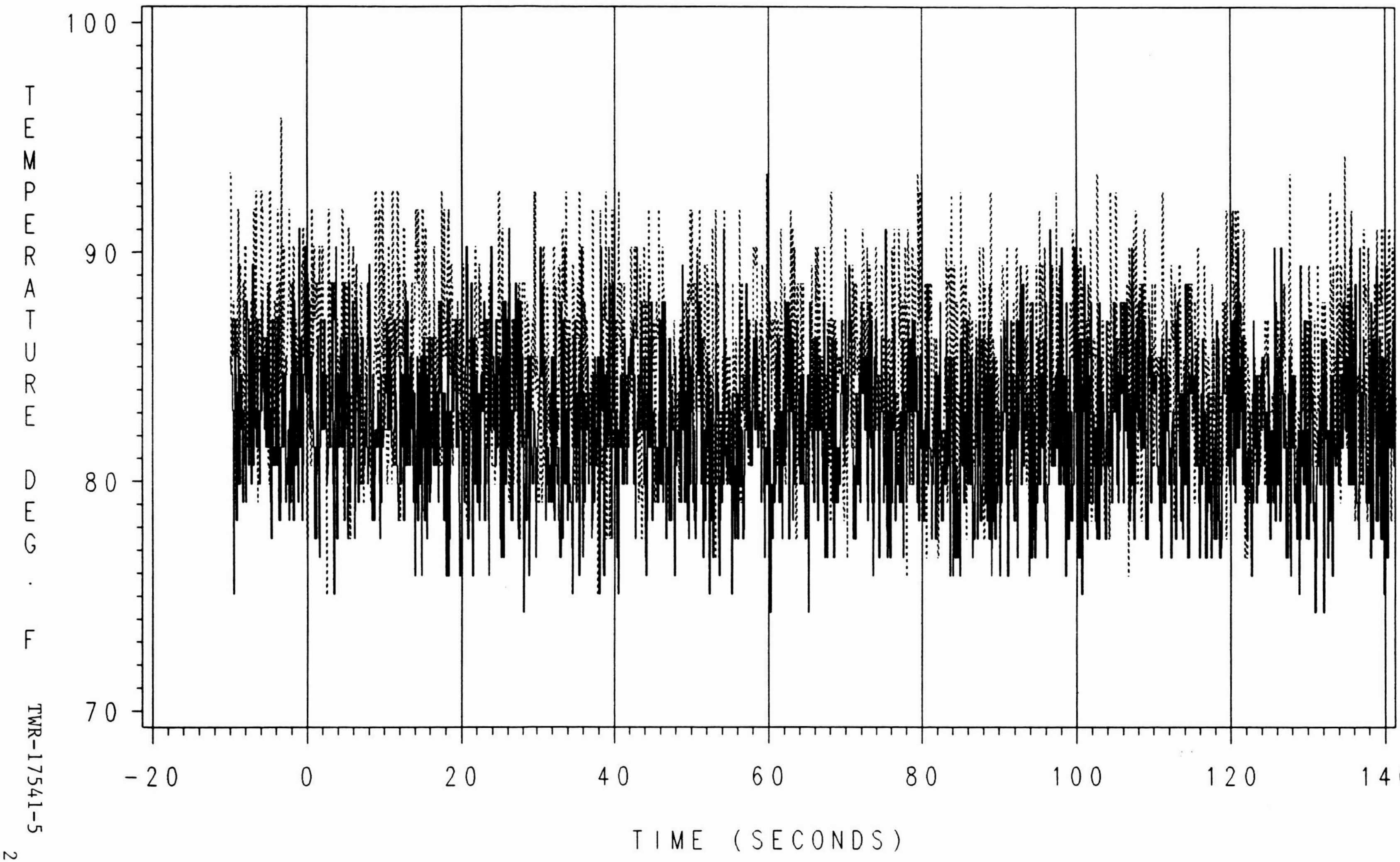


Figure 4.178 STS-27 Nozzle Temperature Gages - Right SRB

RED SOLID LINE = T8620A • 90 DEG.

BLUE DASHED LINE = T8621A • 270 DEG.

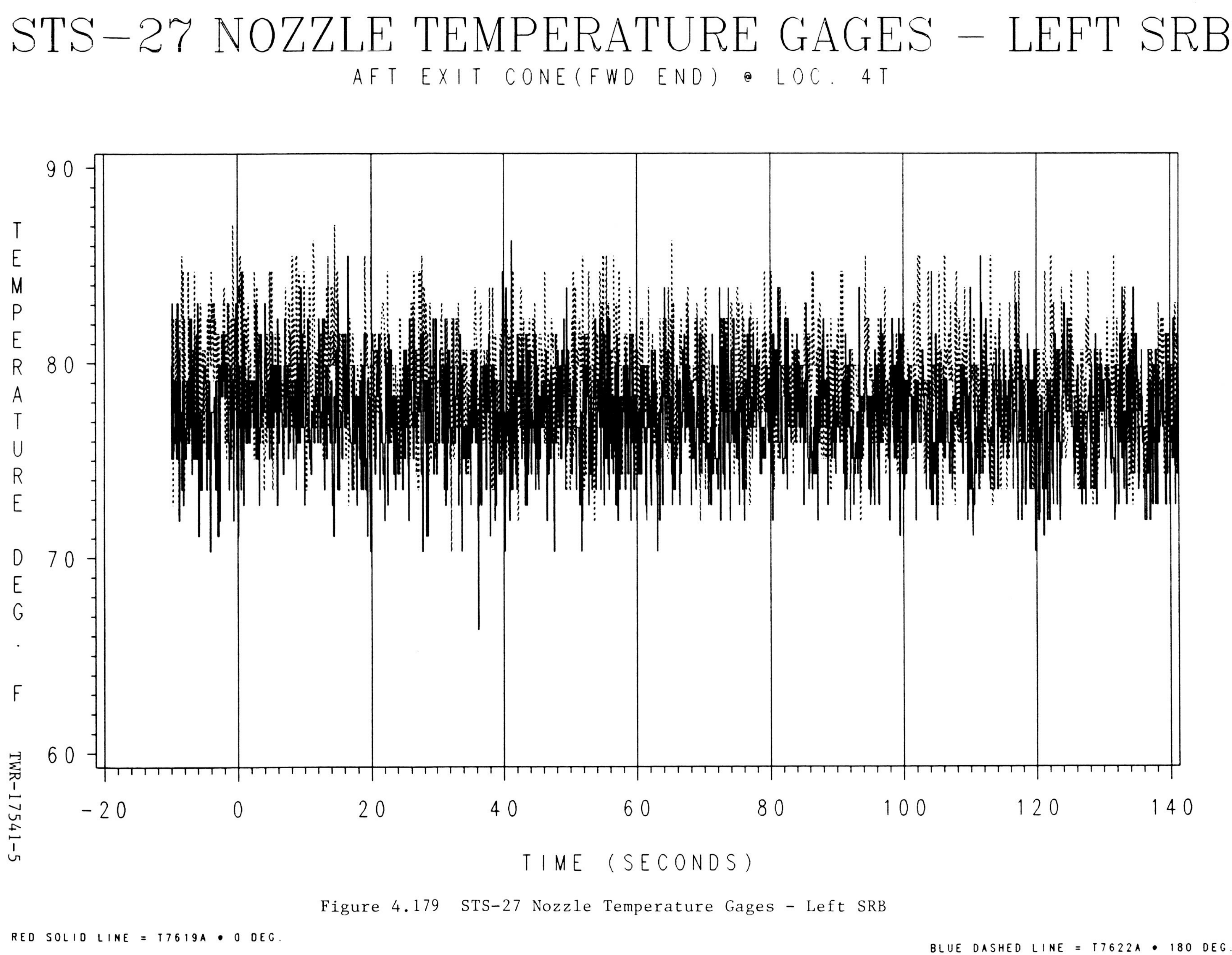


Figure 4.179 STS-27 Nozzle Temperature Gages - Left SRB

STS-27 NOZZLE TEMPERATURE GAGES - RIGHT SRB

AFT EXIT CONE(FWD END) @ LOC. 4T

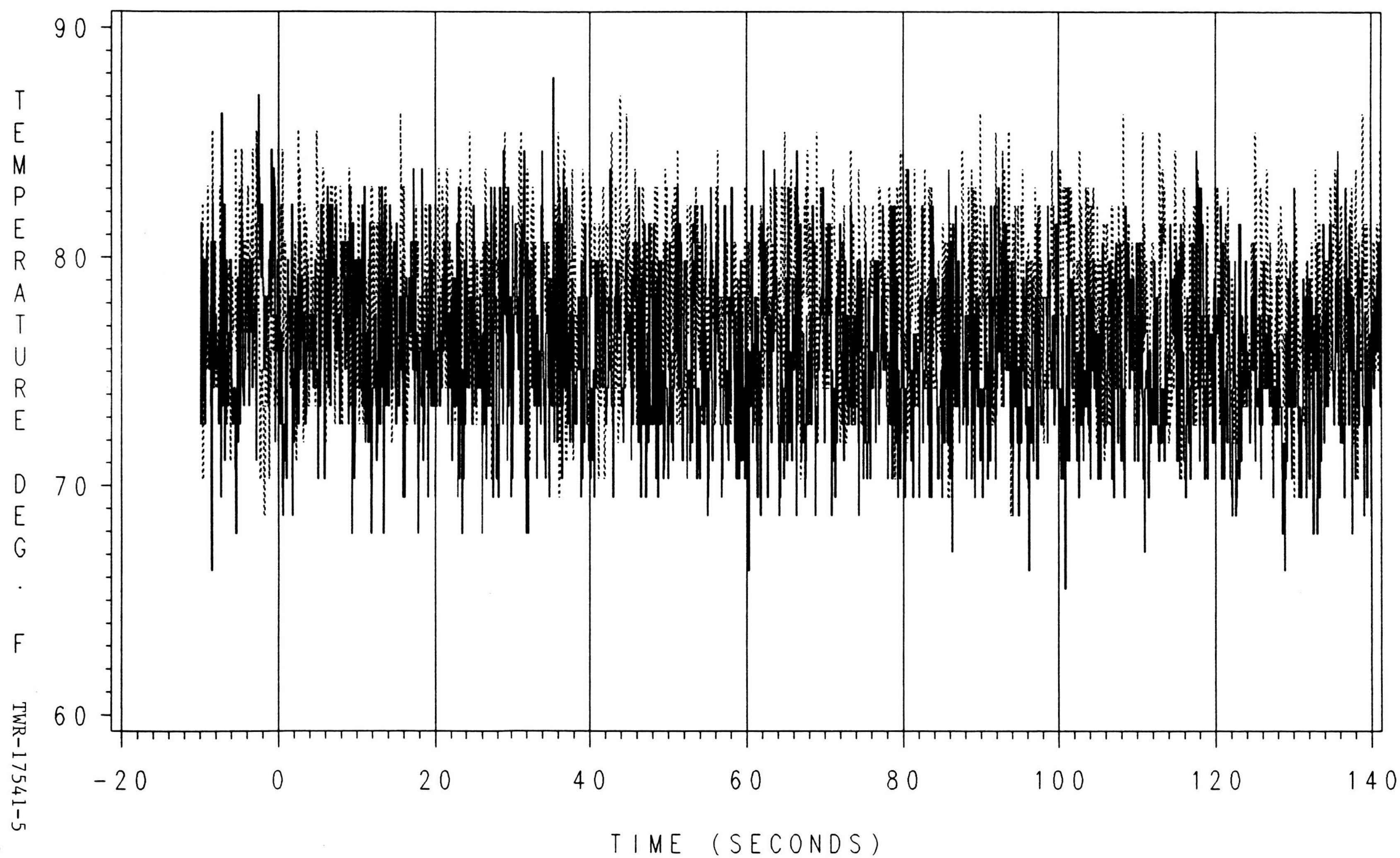


Figure 4.180 STS-27 Nozzle Temperature Gages - Right SRB

RED SOLID LINE = T8619A • 0 DEG.

BLUE DASHED LINE = T8622A • 180 DEG.

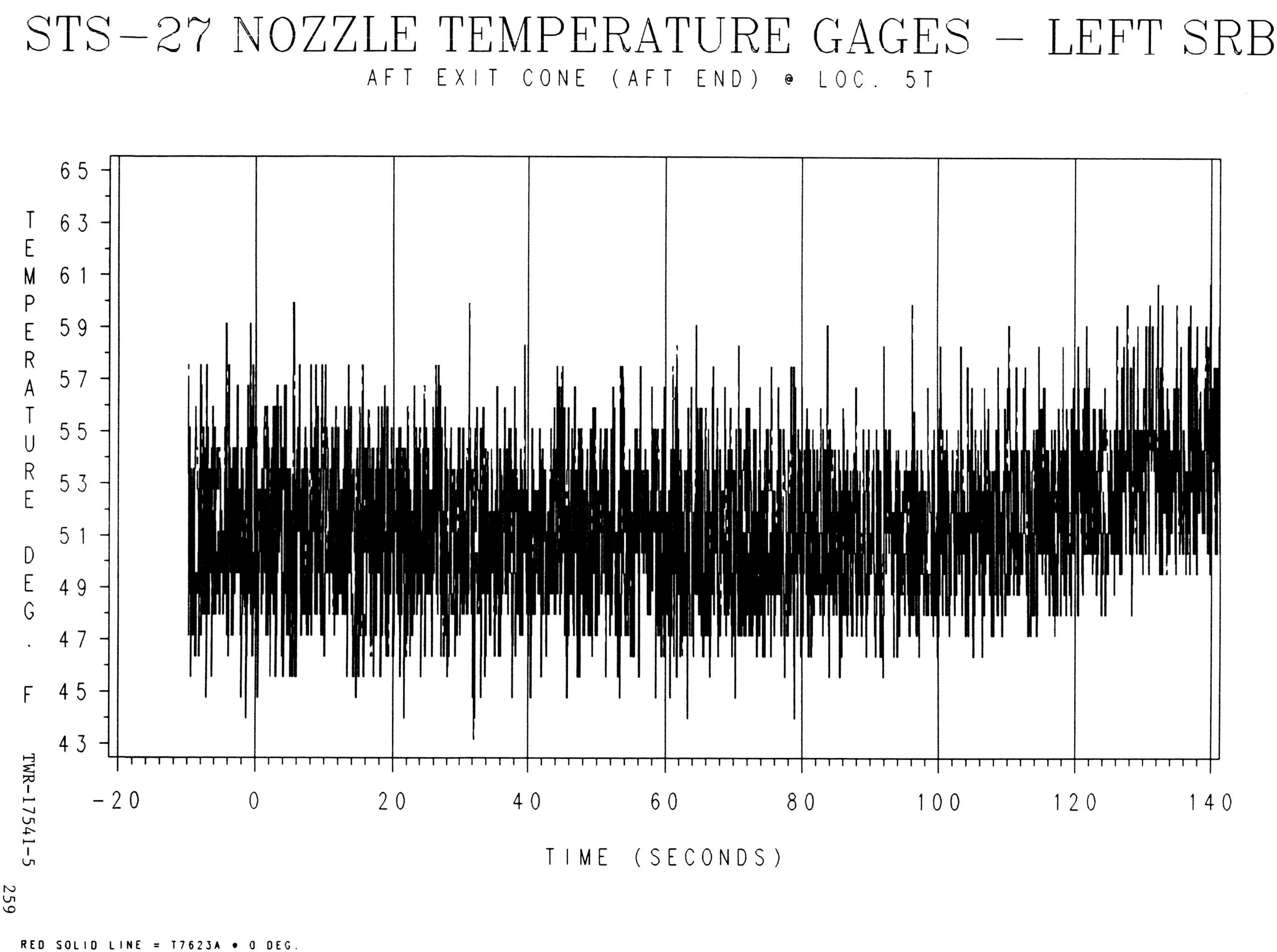
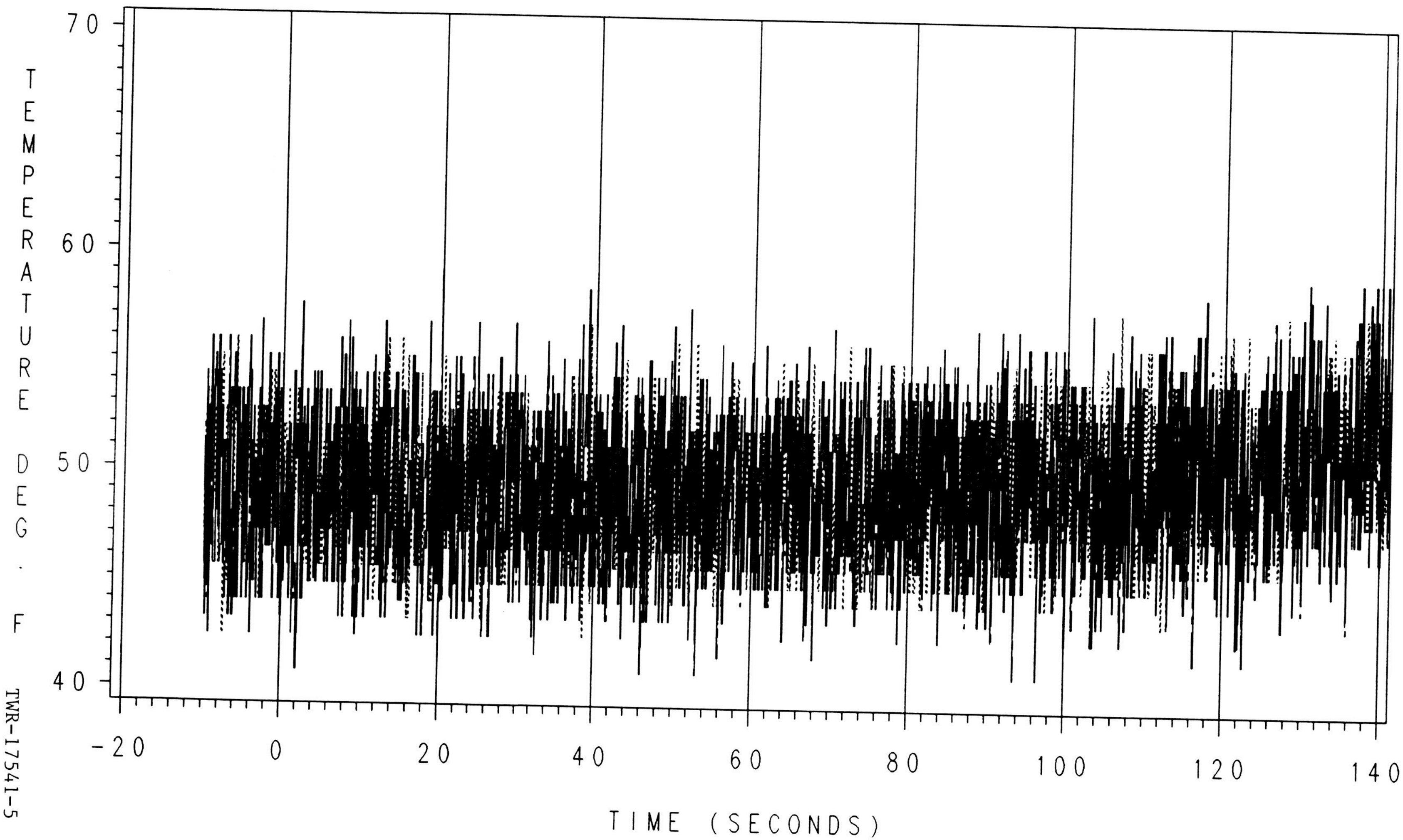


Figure 4.181 STS-27 Nozzle Temperature Gages - Left SRB

STS-27 NOZZLE TEMPERATURE GAGES – RIGHT SRB

AFT EXIT CONE (AFT END) @ LOC. 5T



RED SOLID LINE = T8623A • 0 DEG.

BLUE DASHED LINE = T8624A • 120 DEG.

GREEN DOT-DASHED LINE = T8625A • 240 DEG.

Figure 4.182 STS-27 Nozzle Temperature Gages - Right SRB

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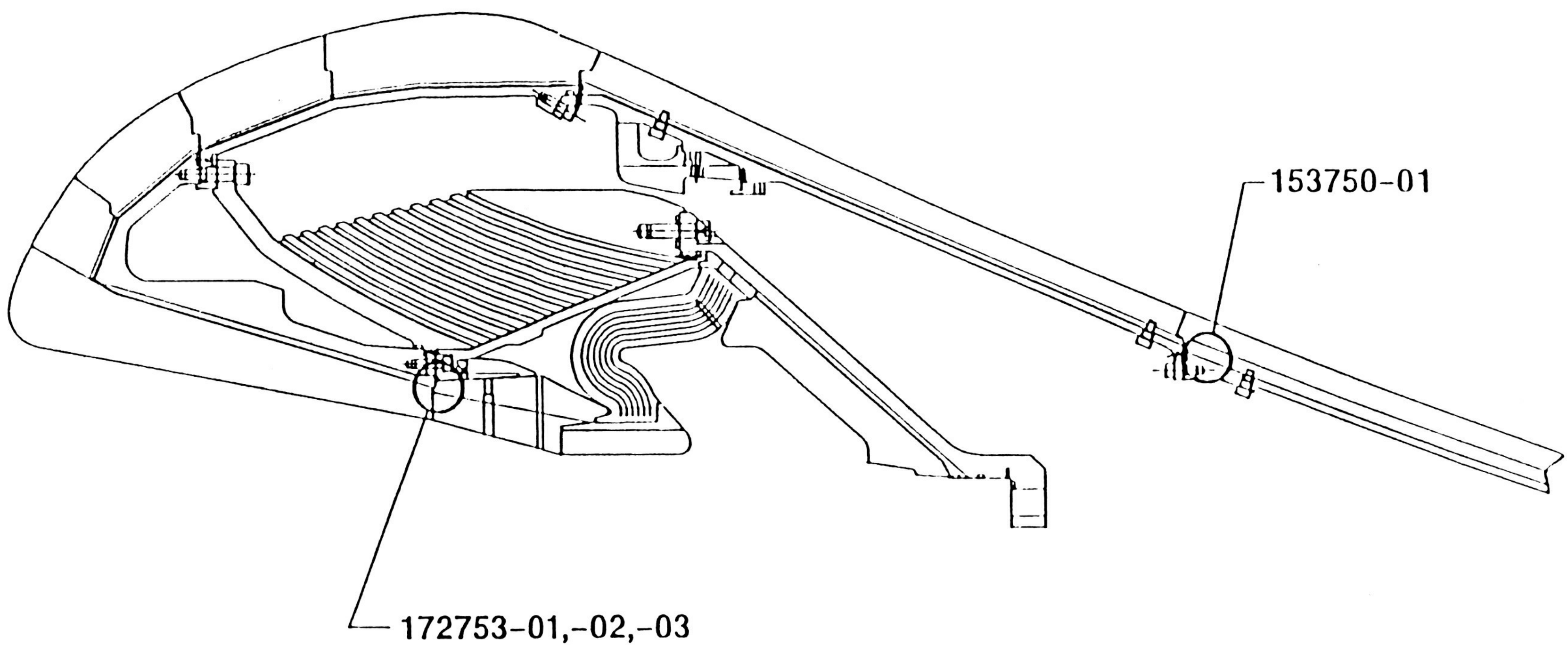
Appendix A

STS-27A and B DRs and PDs

Nonconformance Discussion

Nozzle Assembly—Left Hand Motor



Nonconformance Discussion

DR 172753-01 Nose, Throat, Brg, Cowl Hsg Assy Nozzle — Left Hand Motor

SENIOR MRB CRITERIA: 8 WAIVER No.: NONE

Discrepancy

SB: Verify 0.01 inch to 0.05 inch dry fit dimension on surface "B".

IS: Chamfer area of surface "B" is an interference fit at locations 225 deg and 270 deg. Remainder of dry fit is acceptable.

Disposition

Repair

Justification

MRI results indicate that use of larger than drawing allowed shim sizes (>0.05 in.) between nose cap and cowl insulation has eliminated interference fit condition

Assembly planning was modified to use the maximum dry-fit gap (.059 in.) measurement when determining the thickness of RTV sealant to be applied between the nose cap and cowl

Nonconformance Discussion

DR 172753-02 Nose, Throat, Brg, Cowl Hsg Assy Nozzle Left Hand Motor

SENIOR MRB CRITERIA: 8 WAIVER No.: NONE

Discrepancy

SB: Bond gap at surface "A" shall be 0.01-0.05 in.

IS: Out-of-tolerance condition exists intermittently 360 deg. Maximum condition of 0.059 in. at 225 deg

Disposition

USE-AS-IS

Justification

Increase of 0.009 in. maximum will not affect the joint performance between nose cap and cowl

RTV sealant acts as a high temperature resistant filler. It is not a structural bond

been

Thermal characteristics of joint not altered as long as additional volume has filled in with RTV ~~sealant~~!

Additional gap will not cause additional erosion, washout at the joint, or increase the possibility for circumferential gas flow

No
10-5-88

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FC0154
REV A

Nonconformance Discussion

DR 172753-03 Nose, Throat, Brg, Cowl Hsg Assy Nozzle — Left Hand Motor

SENIOR MRB CRITERIA: 8 WAIVER No.: NONE

Discrepancy

SB: Bond gap at surface "B" shall be 0.01-0.05 in.

IS: Maximum condition of 0.052 in. exists at 315 deg

Disposition

USE-AS-IS

Justification

Increase of 0.002 in maximum will not affect the joint performance between nose cap and cowl ~~insulation~~

RTV sealant acts as a high temperature resistant filler. It is not a structural bond

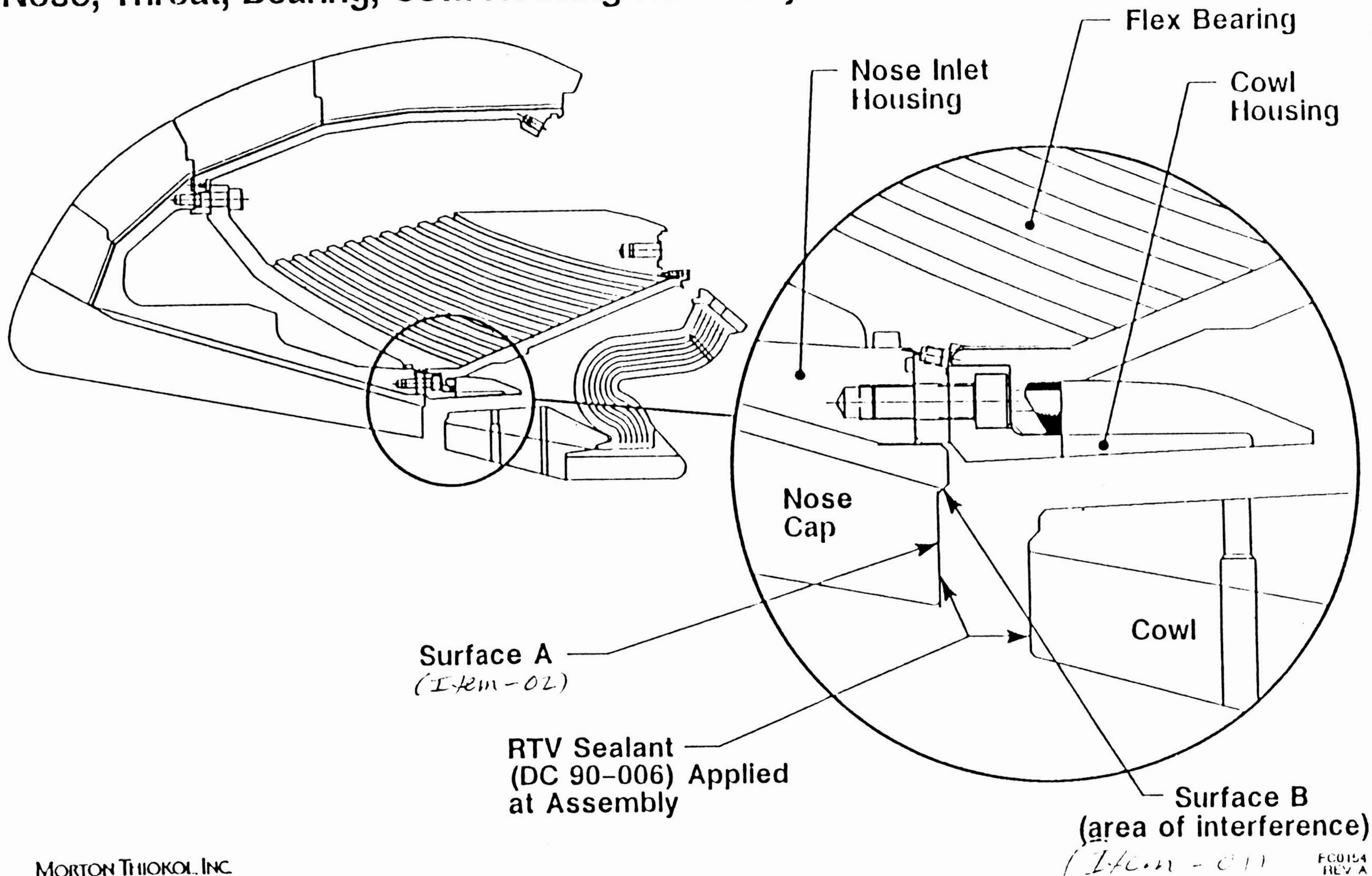
Thermal characteristics of joint not altered as long as additional volume has been filled in with RTV sealant

Additional gap will not cause additional erosion, washout at the joint, or increase the possibility for circumferential gas flow

Nonconformance Discussion

DR 172753-01,-02,-03
Nose, Throat, Bearing, Cowl Housing Assembly Nozzle

Left Hand Motor



Nonconformance Discussion

DR 153750-01 Aft Exit Cone, Second Machine — Left Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW 416

Discrepancy

SB: Low density indications within the glass cloth phenolic (GCP) exceeding 2.500 in. circumferential width X 1.900 in. longitudinal length X 0.020 in. radial depth shall not be accepted

IS: Low density indication (51 deg. to 54 deg.) in the GCP approx. 5.6 in. aft of forward end of aft exit cone. Maximum dimension checks; 3.760 in. circumferential width X 0.700 in. longitudinal length X .040 in. radial depth

Disposition

USE-AS-IS

Justification

Structural analysis show low density indications lie in low stress areas

Worst case condition successfully flown on STS-2B — 4.6 in. circumferential width X 1.90 in. longitudinal length X 0.020 in. radial depth

The glass cloth phenolic is overwrapped parallel to the carbon cloth phenolic (CCP) liner surface

Possibility of GCP delamination propagating to CCP liner is not a concern

Minimum margin of safety in GCP at area of defect is 26.35 at T = 100 sec (includes a 1.4 facto of safe

Across ply and interlaminar shear stress states at minimum margin of safety area are -65 and 132 psi respectively

Waiver Status — Closed

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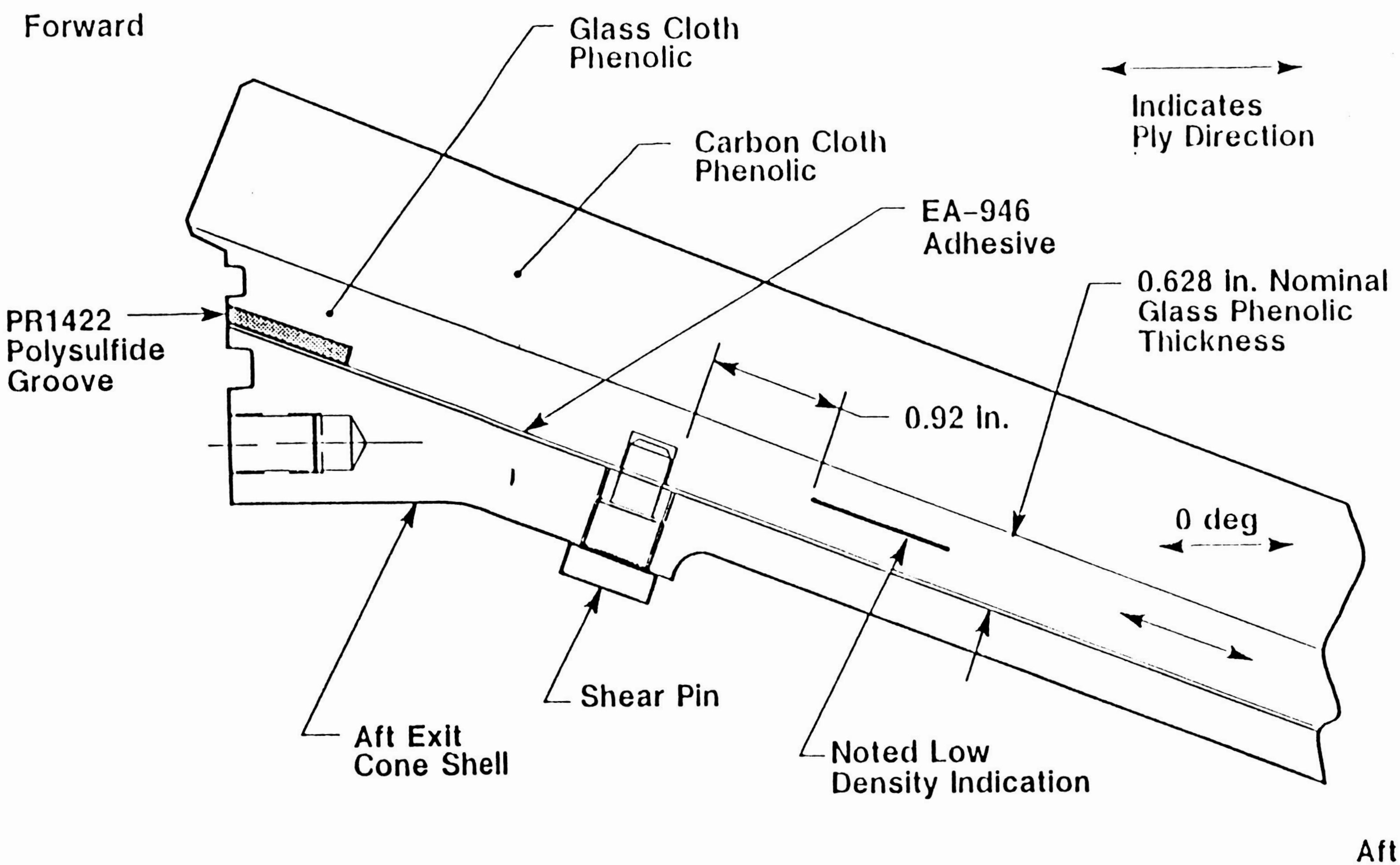
Nonconformance Discussion

DR 153750-01 Low Density Indication



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3.1 Senior MRB Criteria

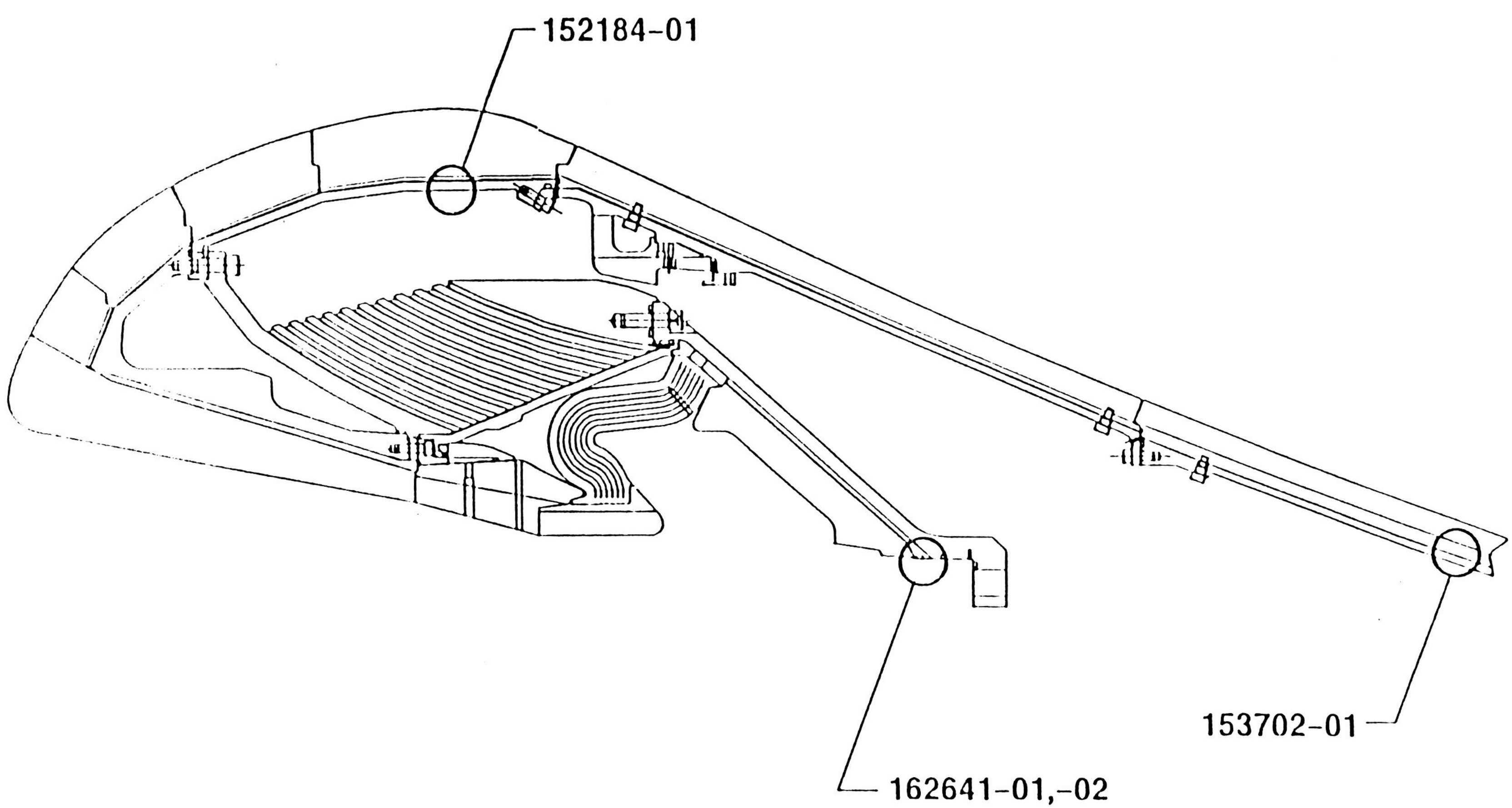
FC0154
REV A

Senior MRB Criteria

1. DRs with criticality 1/1R function and discrepancy which falls outside the SRM DR Experience Data Base (SDEDB)
2. DRs which reduce margin or factor of safety below the SDEDB and CEI spec
3. DRs which accept/allow identifiable linear indication, lack of fusion, cracks, voids, unbonds, delaminations, etc, outside SDEDB
4. DRs resulting in or change to a limited use status for flight hardware
5. DRs resulting in stresses which exceed or lower the endurance limit of infinite life components
6. DRs for first-of-a-kind repair on a criticality 1/1R discrepancy
7. DRs requiring repairs which prevent verification to the original inspection criteria
8. DRs in the opinion of any MRB member that are of borderline nature
9. Critical process departures or DRs requiring a Class I waiver

Nonconformance Discussion

Nozzle Assembly—Right Hand Motor



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REV A

Nonconformance Discussion

DR 162641-01 Fixed Hsg Insulation, Second Machine Right Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW 415

Discrepancy

SB: Low density indications in the glass cloth phenolic shall not exceed 5.000 inches circumferential width, 0.350 inch longitudinal 0.025 inch radial depth

IS: Low density indication in the glass cloth phenolic at extreme aft end, checks 2.70 inches circumferential width, 0.436 inch longitudinal length, 0.018 inch radial depth, located at 210 degrees

Note: Subsequent machining reduced the longitudinal length to 0.254 inch.

Disposition

USE-AS-IS

Justification

Thermal - Structural analysis shows:

Worst case condition analyzed: Gas path through polysulfide and under wiper O-ring to primary O-ring using both maximum thermal and pressure conditions

The minimum margin of safety in the glass phenolic at area of defect for delamination is 5.03 at T=10 sec (includes a 1.4 ~~safety factor~~ factor of safety)

Nonconformance Discussion

DR 162641-01 Fixed Hsg Insulation, Second Machine (Cont) Right Hand Motor

SENIOR MRB   CRITERIA: 9   WAIVER No.: RWW 415

Justification (Cont)

Thermal - Structural analysis shows:

Area of defect is in across ply compression during motor operation.

Compressive stress of 1470 psi combined with 841 psi motor pressure (tensile) results in a net compressive stress of 629 psi at the inboard tip of the low density indication

The delamination will not propagate through the glass cloth phenolic.

Waiver Status

Closed

Nonconformance Discussion

DR 162641-02 Fixed Housing Insulation, Second Machine Right Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW 415

Discrepancy

SB: No wet line indications allowed

IS: Wet line indication located 0.410 in. aft of O-ring groove at 210 degrees, checks 3.60 in. circumferential width, 0.010 inch radial depth, longitudinal length unknown

Disposition

USE-AS-IS

Justification

Thermal - structural analysis shows:

Worst case condition analyzed: 1) Gas path through polysulfide and under wiper O-ring to primary O-ring using both maximum thermal and pressure conditions and 2) assumed delamination in glass due to wetline condition

Area of defect is in across-ply compression during motor operation.

The minimum margin of safety in the glass phenolic at area of defect for delamination is 5.03 at T = 10 sec (includes a 1.4 ~~safety factor~~ factor of safety)

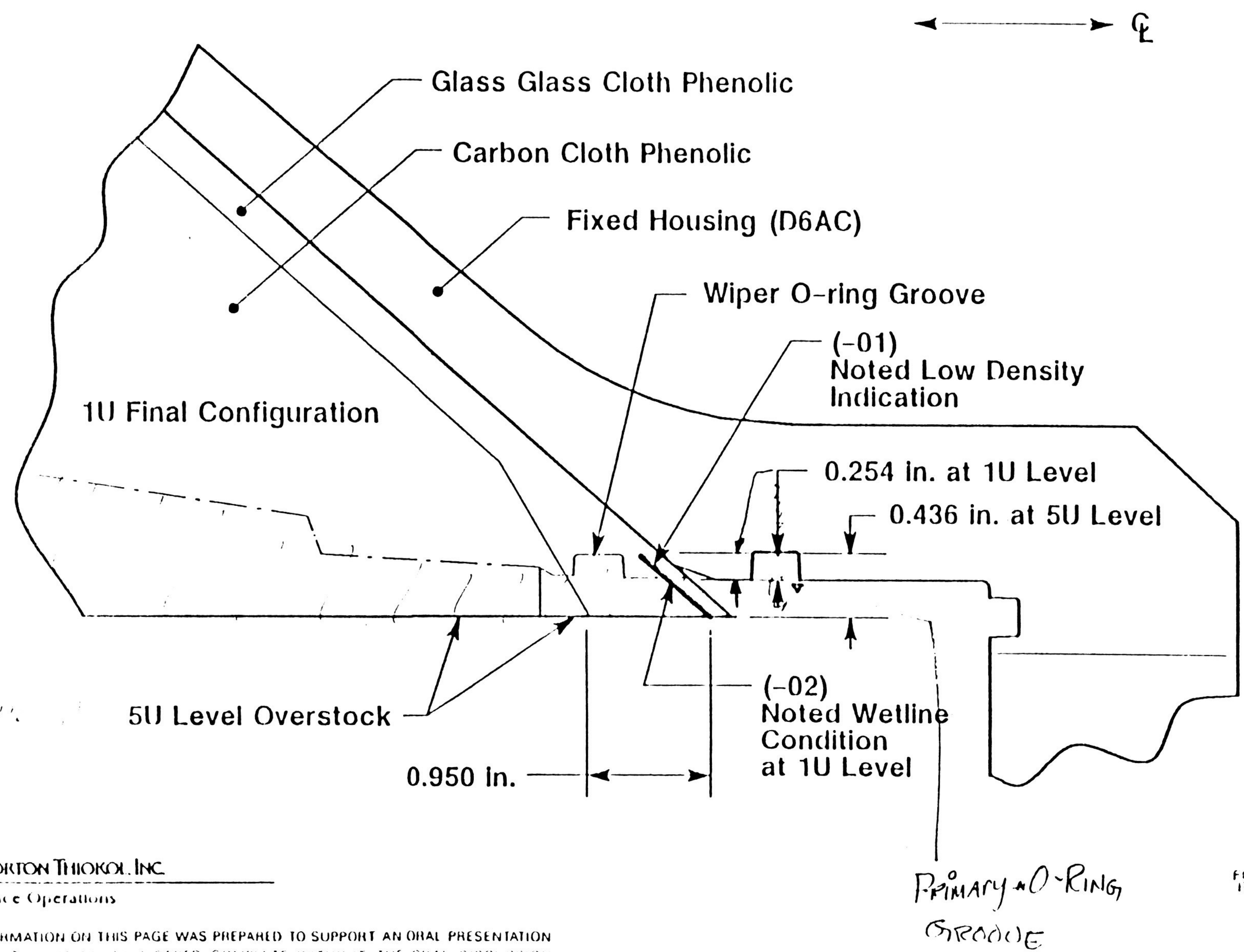
Delamination, due to wetline condition, will not propagate through glass phenolic

Waiver Status

Closed

Nonconformance Discussion

DR 162641-01,-02



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REV A

Nonconformance Discussion

DR 152184-01 Throat Ring, Second Machine — Right Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW 412

Discrepancy

SB: Low density indications which lie along the carbon liner to glass cloth phenolic interface shall be cause for rejection

IS: Approximately 30 low density indications along the carbon liner to glass cloth phenolic liner interface. Extend the full 360 degree circumference, beginning 4.72 in. aft of the forward end of the part running to aft end. Maximum dimension of 0.080 in. longitudinal length, 0.044 in. radial depth

Disposition

USE-AS-IS

Justification

Throat Ring

Historical data shows similar indications in most previous flight and static test throat ring carbon-to-glass phenolic interfaces—worst case condition of 0.120 in. X 0.053 in. existed on SRM-22B throat ring. Flown with acceptable performance space

Low density indications (LDI) at GCP/CCP interface are inherent to design and manufacturing process

A minimum margin of safety of 1.83 was calculated in area of concern. (includes a 1.4 factor of safety) (300 psi maximum tension at 120 sec, 1 in. forward of aft end)

Majority of interface remains in normal compression during motor ~~operations~~ operation

Nonconformance Discussion

3.3-16

DR 152184-01 Throat Ring, Second Machine (Cont) — Right Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW 412

Justification (Cont)

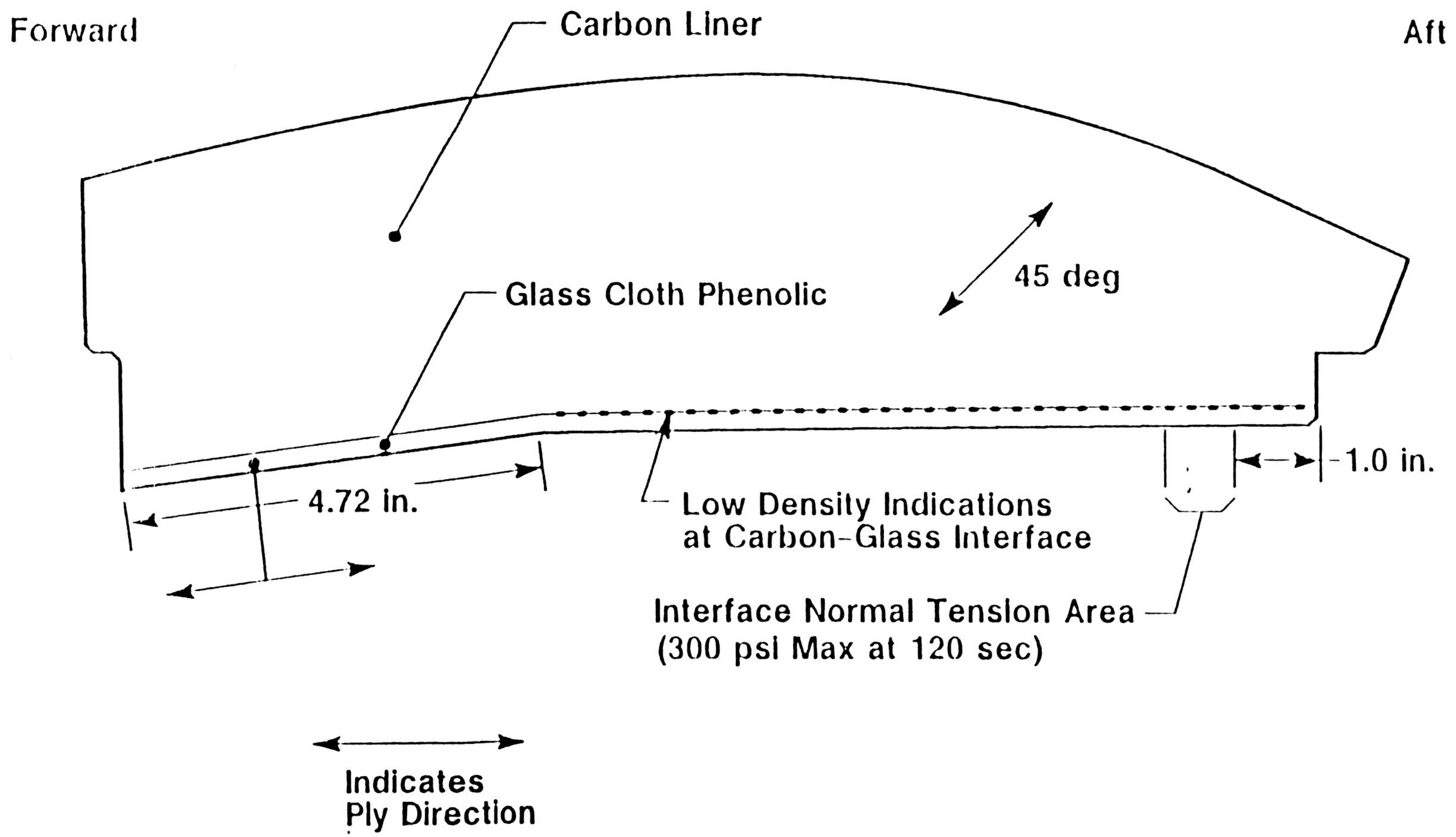
- Throat Ring
  - Testing per TWR-18458 verified interface strength is not compromised by LDIs
  - New criteria approved by NASA and implemented allows 0.181 in. longitudinal length X 0.053 in. radial depth LDI along GCP/CCP interface

Waiver Status

- Closed

Nonconformance Discussion

DR 152184-01 Throat Ring Low Density Indications



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REV A

Nonconformance Discussion

DR 153702-01 Aft Exit Cone Assembly — Right Hand Motor

SENIOR MRB CRITERIA: 9 WAIVER No.: RWW419

Discrepancy

SB: Cause, for rejection shall be low density indications which lie along the carbon cloth phenolic liner and glass cloth phenolic interface.

IS: Low density indications (LDI) exist at carbon-to-glass interface, 139 nonmeasurable low density indications, evenly dispersed from aft of compliance ring to aft end of part

Disposition

USE-AS-IS

Justification

Historical data Indicates similar conditions in a sample of previous flight and static test aft exit cones (SRM-18A, 19A, DM-7, ETM-1A, DM-8, DM-9, ~~ETM-1A~~, QM-6)

Testing per TWR-18458 verified interface strength is not compromised by LDIs

LDIs at CCP/GCP interface are inherent to design and manufacturing process

New criteria approved by NASA and implemented allows 0.104 in. longitudinal length X 0.030 in. radial depth LDI along CCP/GCP interface

Waiver Status

Closed

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Space Operations

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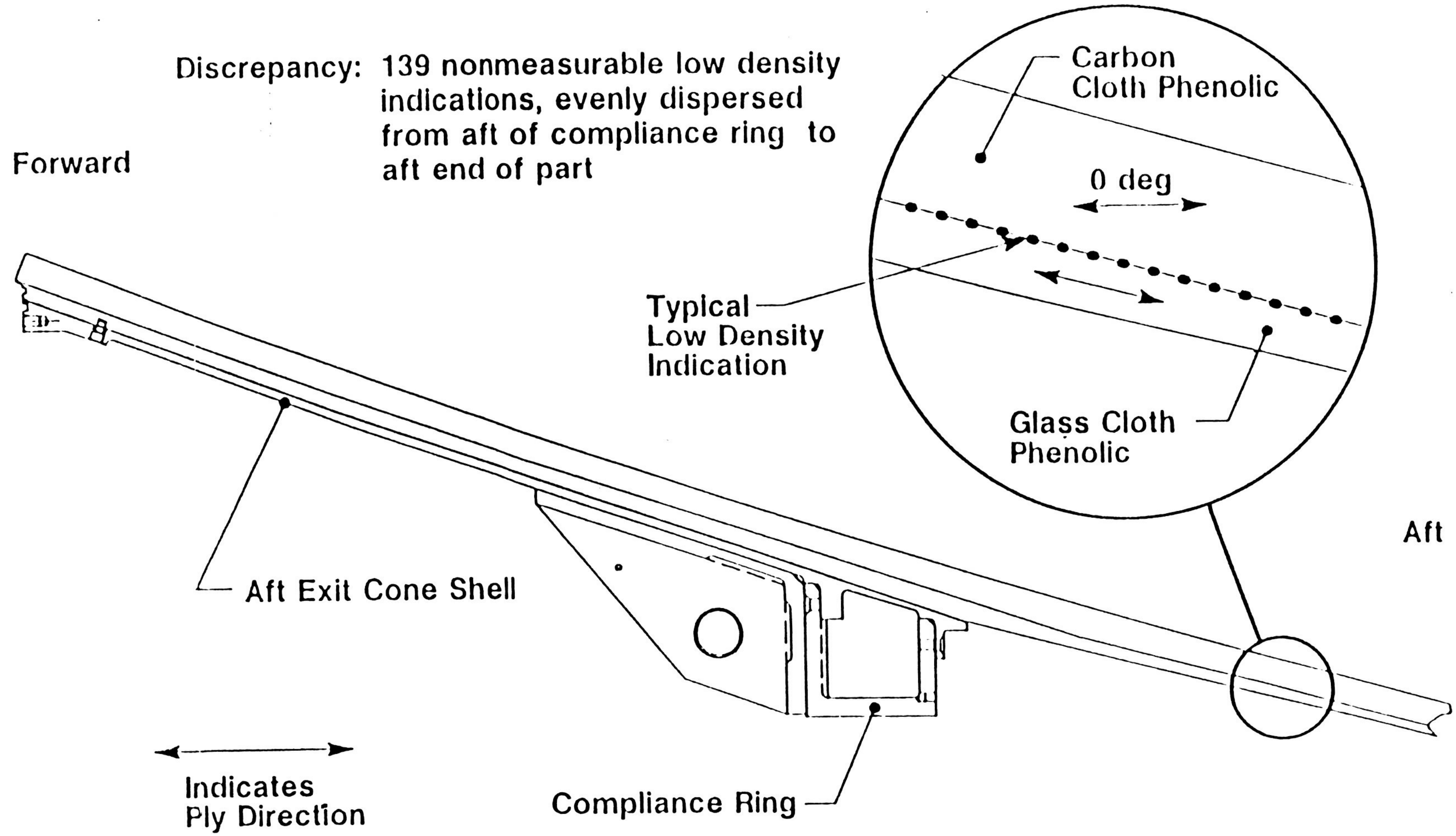
REV A

Nonconformance Discussion

DR 153702-01 Aft Exit Cone Low Density Indications

Discrepancy: 139 nonmeasurable low density indications, evenly dispersed from aft of compliance ring to aft end of part



FC0154
REV A

Appendix B

STS-27A and B Nozzle Component Program Team Recommendations to the RPRB

1-25-89

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

STS-27 NOZZLE COMPONENT PROGRAM TEAM CONVEINED 21 DECEMBER 1988, AND 24 JANUARY 1989. THE TEAM REVIEWED ALL PR'S THAT WERE WRITTEN DURING KSC DISASSEMBLY OPERATIONS.

- 5 SQUAWKS WERE WRITTEN AT KSC
- ALL 5 SQUAWKS WERE ELEVATED TO KSC PR'S
- THE NOZZLE COMPONENT PROGRAM TEAM CLASSIFIED 2 OF THE PR'S AS "OBSERVATIONS" AND 2 OF THE PR'S AS "MINOR ANOMALIES". THE TEAM IS AWAITING LAB RESULTS TO CLASSIFY THE REMAINING PR.

C-4

NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THE NOZZLE COMPONENT PROGRAM TEAM CONSISTS OF THE FOLLOWING MEMEBERS:

PROGRAM OFFICE	D. NISONGER
PROGRAM MANAGEMENT	E. DIEHL
PROJECT ENGINEERING	D. WAGNER
DESIGN ENGINEERING	
o NOZZLE DESIGN	S. MEYER, R. GEORGE
o NOZZLE STRUCTURES	D. BRIGHT
o SEALS	K. BAKER
SYSTEMS ENGINEERING	
o P & AD	S. OLSON, N. TOWNSEND
RELIABILITY	C. WALKER, J. RICHARDS
QUALITY ASSURANCE	G. NIELSON
MANUFACTURING ENGINEERING	J. LEIBOLD

ANOMALY CLASSIFICATION CRITERIA:

REMAINS OBSERVATION	ANOMALY		
	MINOR	MAJOR	Critical
° REQUIRES NO SPECIFIC ACTION	° REQUIRES CORRECTIVE ACTION, BUT HAS NO IMPACT ON: - MOTOR PERFORMANCE - PROGRAM SCHEDULE ° DOES NOT REDUCE USABILITY OF PART FOR ITS INTENDED FUNCTION ° COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE IN COMBINATION WITH OTHER ANOMALY ° SIGNIFICANT DEPARTURE FROM THE HISTORICAL DATA BASE	° COULD CAUSE FAILURE IN COMBINATION WITH OTHER ANOMALY ° COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE ° PROGRAM ACCEPTANCE OF CAUSE, CORRECTIVE ACTION, AND RISK ASSESSMENT REQUIRED BEFORE SUBSEQUENT STATIC TEST/FLIGHT	° VIOLATES CEI SPEC REQUIREMENTS ° COULD CAUSE FAILURE AND POSSIBLE LOSS OF MISSION/LIFE ° MANDATORY RESOLUTION BEFORE SUBSEQUENT STATIC TEST/FLIGHT

NOTE: THIS CRITERIA IS TO BE APPLIED TO THE SPECIFIC OBSERVED "POTENTIAL ANOMALY" AS IT RELATES TO THE OBSERVED ARTICLE AND AS IT RELATES TO SUBSEQUENT ARTICLES.

PR # PV6-116611

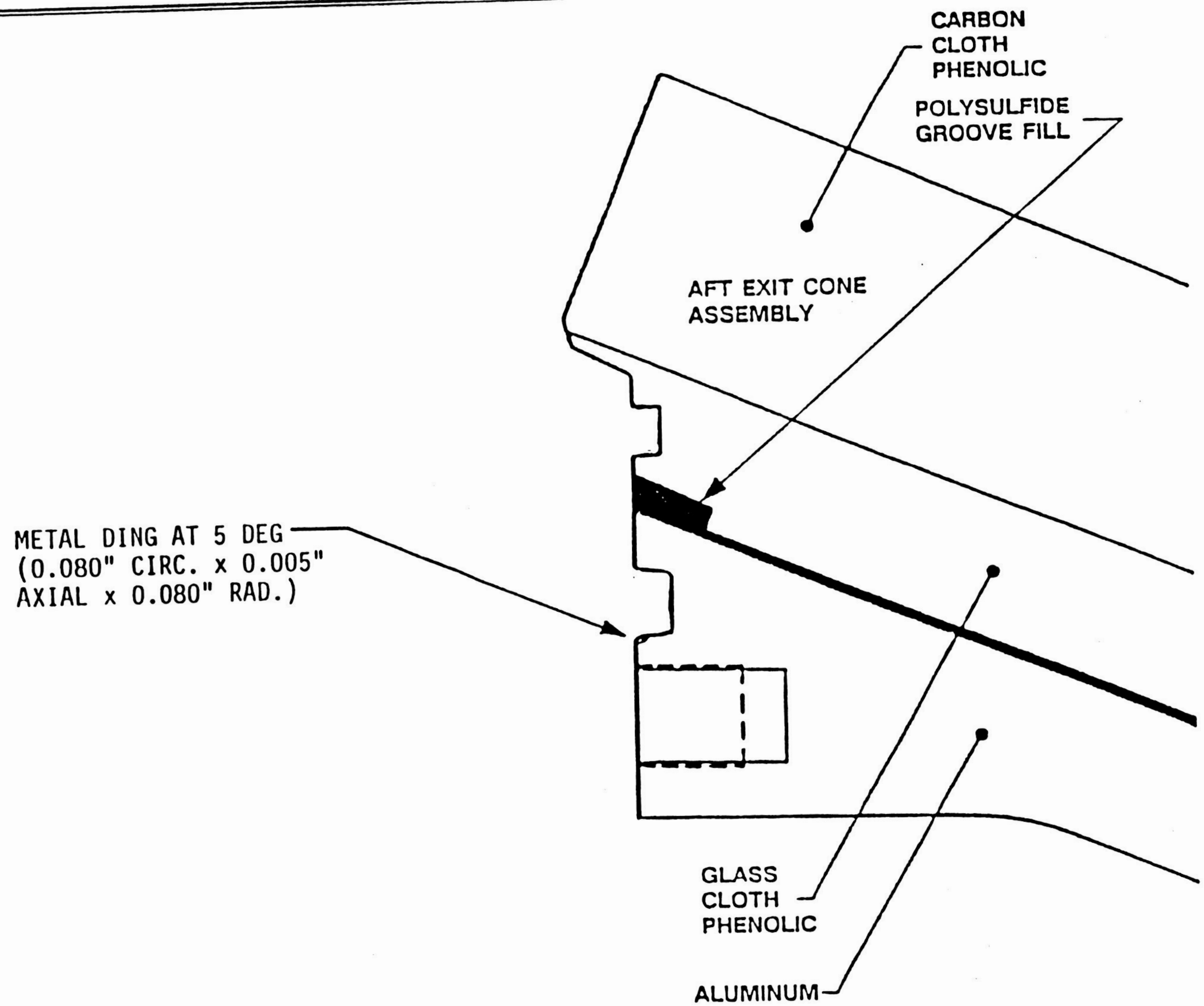
DESCRIPTION: THE (RH) AEC SHELL FWD. END SHOWED A METAL DING ON THE O.D. CORNER OF THE SECONDARY O-RING GROOVE. THE DING WAS LOCATED AT 5 DEG AND MEASURED 0.080 IN. CIRCUMFERENTIALLY X 0.005 IN. AXIALLY X 0.080 IN. RADIALLY. THE METAL DING OCCURRED DURING TRANSPORTATION TO THE HANGER FLOOR OR DURING BREAK OVER.

HISTORY: METAL DAMAGE HAS NOT PREVIOUSLY BEEN OBSERVED ON AFT EXIT CONE FORWARD ENDS DUE TO DISASSEMBLY OPERATIONS

RELIABILITY RECOMMENDATION: NO SIGNIFICANT PROBLEM REPORT (SPR)

TEAM CLASSIFICATION: MINOR ANOMALY

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS



STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS (CONT.)

PR # PV6-116611 (CONT.)

JUSTIFICATION: REQUIRES CORRECTIVE ACTION, BUT HAS NO IMPACT ON MOTOR PERFORMANCE OR PROGRAM SCHEDULE

COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE IF THE DAMAGE OCCURRED ON THE SEALING SURFACE OF THE O-RING GROOVE

RECOMMENDATION: SPC DISASSEMBLY PERSONNEL REVIEW PROCEDURES AND MAKE CHANGES TO PREVENT RECURRENCE.

THIS PR WAS FORWARDED TO MTI-LSS OFFICE FOR DISPOSITION

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR # PV6-116315

DESCRIPTION: DURING (RH) AFT EXIT CONE/FORWARD EXIT CONE BOLT REMOVAL, 12 BOLTS WERE FOUND TO BE VISIBLY BENT FROM THE 0 - 90 DEG QUADRANT. THE BOLT THREADS WERE ALSO FLATTENED.

HISTORY: BENT AFT EXIT CONE FIELD JOINT BOLTS HAVE NOT BEEN OBSERVED ON PAST FLIGHT NOZZLES

RELIABILITY RECOMMENDATION: SPR DR 4-5/128

TEAM CLASSIFICATION: MINOR ANOMALY

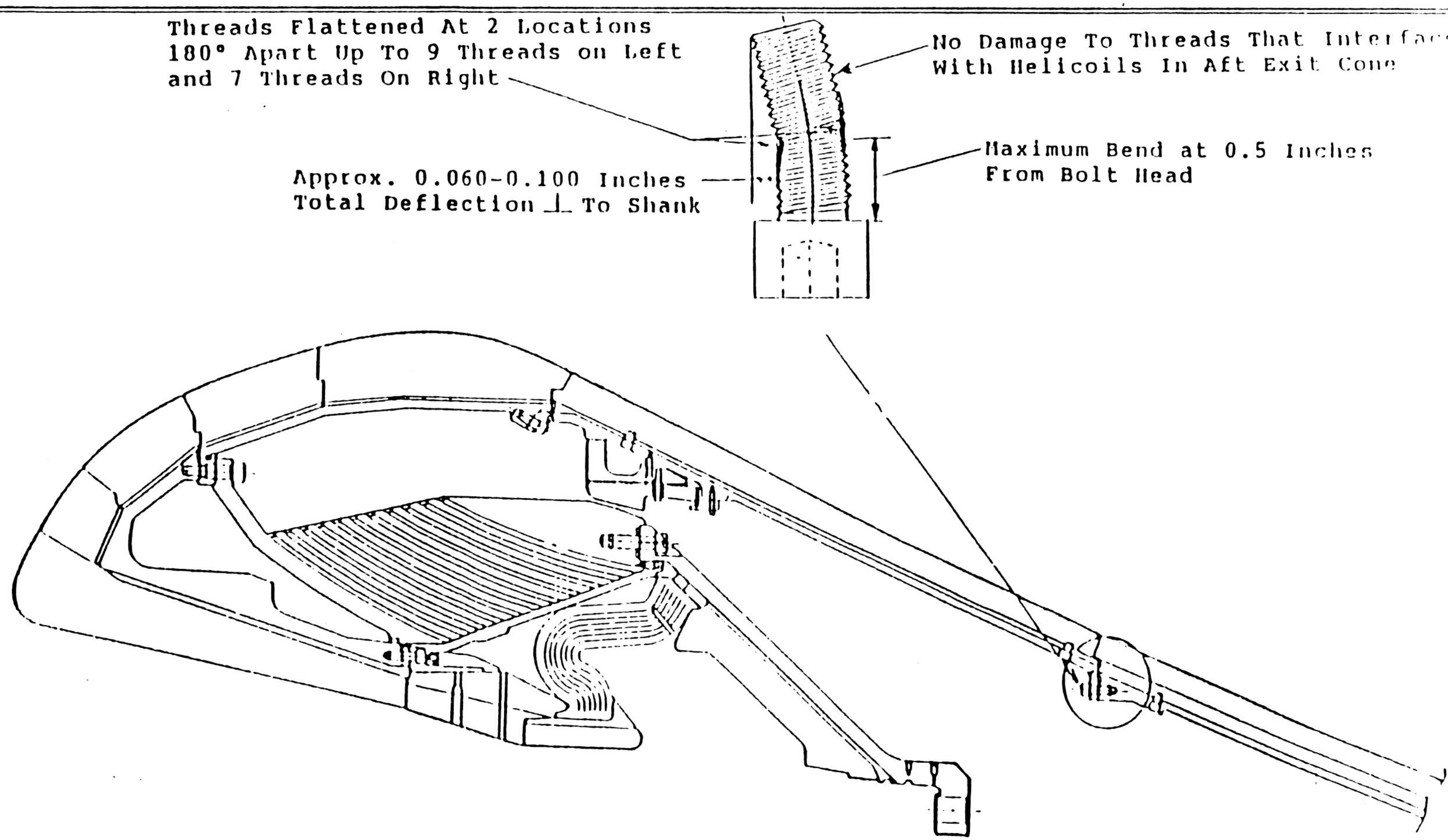
JUSTIFICATION:

SIGNIFICANT DEPARTURE FROM HISTORICAL DATA BASE

STRUCTURES (MEMO L223:FY89:639) CONCLUDED THE BOLTS WERE BENT AT SPLASHDOWN

- MOTOR CHAMBER PRESSURE AND ACTUATOR LOADS DURING POWERED FLIGHT WERE NORMAL. THIS INDICATES EXTERNAL LOADS TO NOZZLE WERE NOMINAL DURING FLIGHT

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS



Physical Description of Bent Bolts in STS-27B Aft Exit Cone Field Joint

ORIGINAL PAGE IS OF POOR QUALITY

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS (CONT)

PR # PV6-116315 (CONT)

JUSTIFICATION (CONT):

- INSTRUMENTATION ON THE NOZZLE SHOWS NO UNUSUAL/ANOMALOUS THERMAL OR STRUCTURAL READINGS DURING POWERED FLIGHT

- A REVIEW OF THE SPLASHDOWN VIDEO SHOWS THE (RH) BOOSTER KNIFED SIDEWAYS AFTER AFT SKIRT CONTACT WITH THE WATER. "SLAP DOWN" EVENT WOULD IMPOSE LARGE ASYMMETRIC LOADS ON THE NOZZLE

- SNUBBER DAMAGE INDICATES THE (RH) NOZZLE SAW UNUSUALLY HIGH WATER IMPACT LOADS

RECOMMENDATION: CONTINUE INSPECTING FOR FUTURE OCCURRENCES. ADD LIMITS TO POST-FIRE ENGINEERING EVALUATION LIMITS (PEEL) DOCUMENT IF OBSERVATIONS CONTINUE

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR # PV6-116791

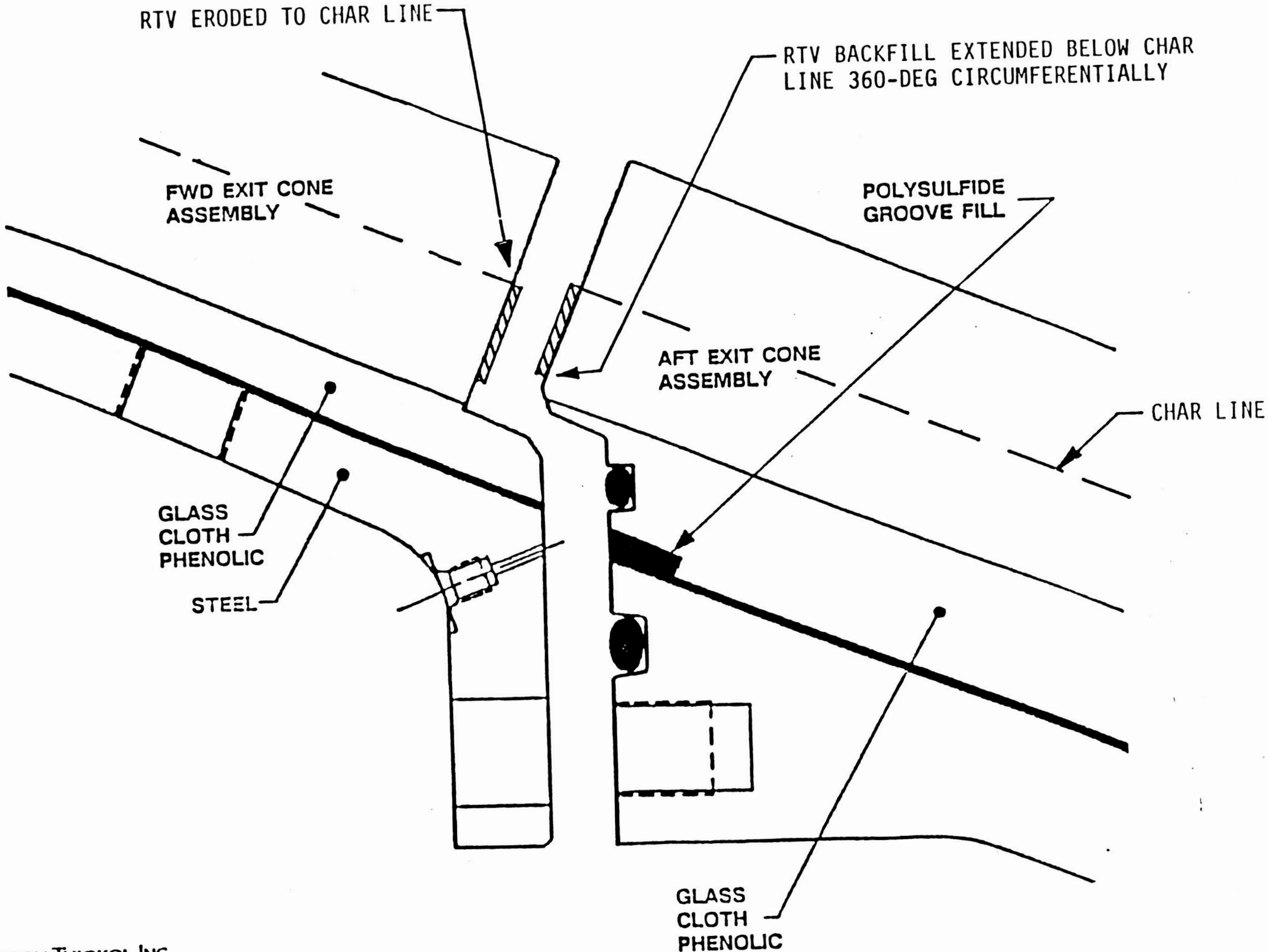
DESCRIPTION: THE (RH) AFT EXIT CONE FIELD JOINT RTV BACKFILL DID NOT EXTEND TO THE PRIMARY O-RING GROOVE 360 - DEG CIRCUMFERENTIALLY. THERE WAS NO BLOWBY, EROSION OR HEAT EFFECT OBSERVED TO THE PRIMARY O-RING. A NASA INSPECTOR FELT THAT THE BACKFILL CONDITION WAS ANOMALOUS. THE INITIATED SQUAWK WAS SIGNED IN NON-CONCURRENCE BY BOTH MTI AND NASA ENGINEERS.

HISTORY: THE RTV BACKFILL DEPTH OBSERVED ON THE STS-27B (RH) AEC FIELD JOINT WAS TYPICAL OF PAST FLIGHT AND STATIC TEST NOZZLE JOINTS.

RELIABILITY RECOMMENDATION: NO SPR

TEAM CLASSIFICATION: OBSERVATION

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS



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STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS (CONT.)

PR # PV6-116791 (CONT.)

JUSTIFICATION: THIS IS NOT A FLIGHT ISSUE. THE DESIGN GOAL OF NOZZLE JOINT RTV BACKFILLS IS TO FILL BELOW THE JOINT CHAR LINE. THE STS-27B (RH) AEC FIELD JOINT SHOWED RTV FILLING BELOW THE JOINT CHAR LINE 360 - DEG CIRCUMFERENTIALLY

RECOMMENDATION:

DEFINE ACCEPTABLE LIMITS OF RTV BACKFILL DEPTHS IN KSC POSTFIRE ENGINEERING EVALUATION LIMITS DOCUMENT (PEEL) TWR-18680 VOL. V

- LIMITS ESTABLISHED ARE UNDER REVIEW BY NASA

DO NOT WRITE THIS OBSERVATION UP ON A SQUAWK FORM IN FUTURE

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR # PV6-116900

DESCRIPTION: THE ALIGNMENT PIN ON THE (RH) FIXED HOUSING AT 91.8 DEG SHOWED AN AXIAL CRACK EXTENDING ALONG THE LENGTH OF THE PIN

HISTORY: FIRST TIME OBSERVED

RELIABILITY RECOMMENDATION: NO SPR

TEAM CLASSIFICATION: OBSERVATION

JUSTIFICATION: THIS IS NOT A FLIGHT ISSUE OR HARDWARE REUSE PROBLEM.

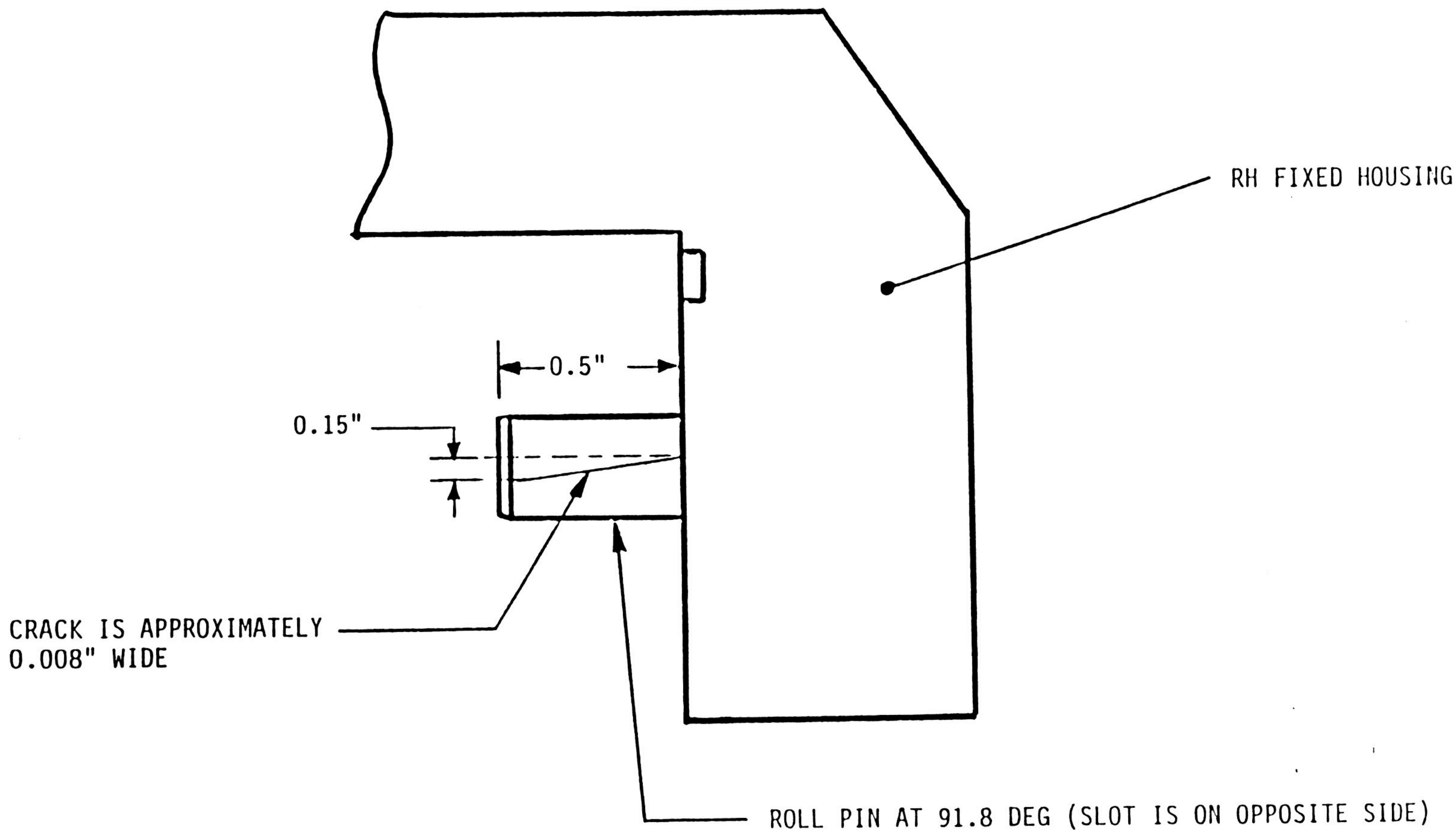
RECOMMENDATION:

CONTINUE INSPECTING FOR FUTURE OCCURRENCES. ADD LIMITS TO POST-FIRE ENGINEEIRNG EVALUATION LIMITS (PEEL) DOCUMENT IF OBSERVATIONS CONTINUE.

AN INSPECTION POINT WILL BE ADDED TO PLANNING TO INSPECT THE LOCATOR PIN AFTER INSTALLED IN THE FIXED HOUSING (EFFECTIVE FLIGHT 6).

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR# PV6-116900



STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR # PV6-116619

DESCRIPTION: FOLLOWING AFT EXIT CONE DEMATE, A WHITE RUBBERY SUBSTANCE WAS OBSERVED ON THE FWD. EXIT CONE EA946 ADHESIVE BONDLINE AFT END. THE WHITE SUBSTANCE WAS OBSERVED INTERMITTENTLY AROUND THE CIRCUMFERENCE ON BOTH THE (RH) & (LH) NOZZLES. A SAMPLE WAS TAKEN AND A KSC LAB ANALYSIS IS CURRENTLY UNDERWAY.

HISTORY: FIRST TIME OBSERVED

RELIABILITY RECOMMENDATION: AWAITING KSC LAB ANALYSIS

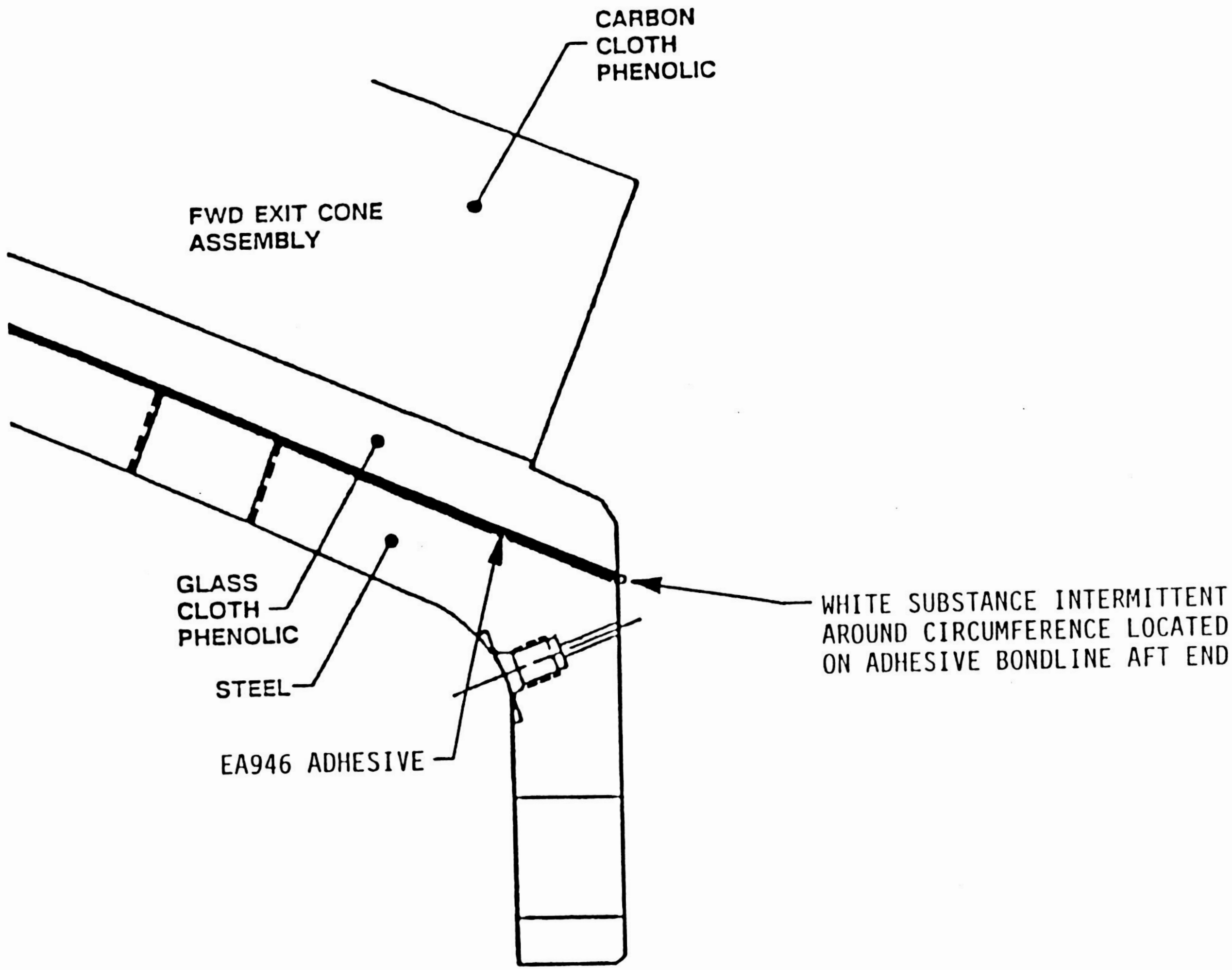
TEAM CLASSIFICATION: AWAITING KSC LAB ANALYSIS

RECOMMENDATION:

- COMPLETE LAB ANALYSIS

- THE SUBSTANCE IS BELIEVED TO HAVE BEEN IN THE JOINT AT ASSEMBLY. THIS PR HAS BEEN FORWARDED TO MTI-LSS OFFICE FOR DISPOSITION. RECOMMEND LSS OFFICE REVIEW ASSEMBLY INSPECTIONS AND PROCEDURES AND MAKE CHANGES TO PREVENT RECURRENCE.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS (CONT.)



STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THE STS-27 NOZZLE COMPONENT PROGRAM TEAM CONVENED 3 MARCH 1989 TO REVIEW THE STS-27 A&B CLEARFIELD OBSERVATIONS

- THE TEAM INITIALLY CLASSIFIED 3 CLEARFIELD OBSERVATIONS AS POTENTIAL ANOMALIES
- AFTER FURTHER REVIEW 2 POTENTIAL ANOMALIES WERE REDUCED TO OBSERVATIONS AND 1 POTENTIAL ANOMALY WAS CLASSIFIED AS A MINOR ANOMALY
- A STS-27 KSC PR IS RE-ADDRESSED AT THE END OF THIS PRESENTATION. BASED ON RECENT LAB ANALYSIS THE TEAM IS RECOMMENDING CLASSIFYING THE PR AS MINOR ANOMALY

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THE NOZZLE COMPONENT PROGRAM TEAM CONSISTS OF THE FOLLOWING MEMBERS:

PROGRAM OFFICE		D. NISONGER
PROGRAM MANAGEMENT	*	E. DIEHL
PROJECT ENGINEERING	*	D. WAGNER
DESIGN ENGINEERING		
o NOZZLE DESIGN	*	S. MEYER, R. GEORGE
o NOZZLE STRUCTURES		D. BRIGHT
o SEALS	*	K. BAKER
SYSTEMS ENGINEERING		
o P & AD		J. BAILEY *
RELIABILITY		C. WALKER, J. RICHARDS, G. CONOVER *
QUALITY ASSURANCE		G. NIELSON
MANUFACTURING ENGINEERING		J. LEIBOLD

* ATTENDEES

ANOMALY CLASSIFICATION CRITERIA:

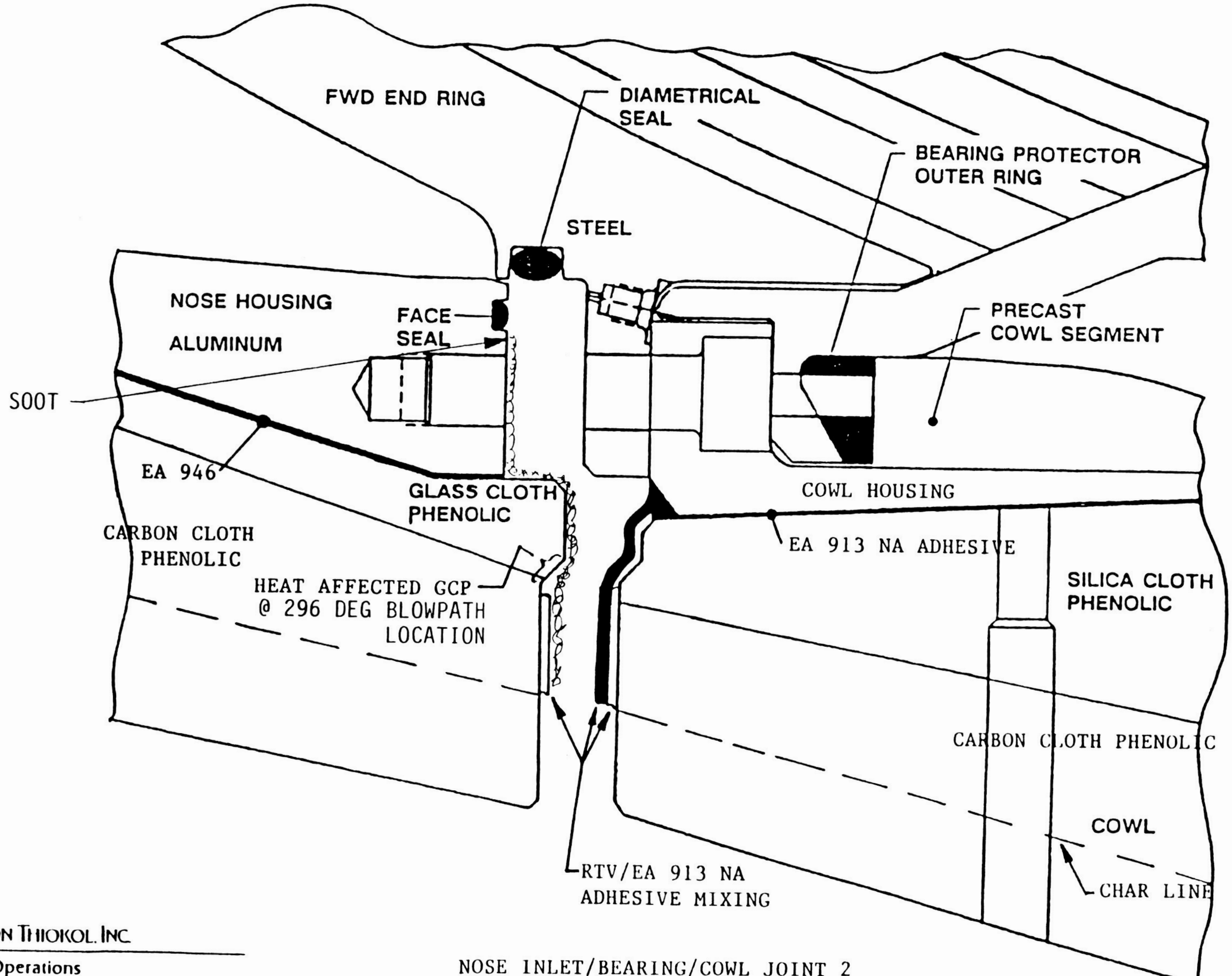
REMAINS OBSERVATION	ANOMALY		
	MINOR	MAJOR	Critical
• REQUIRES NO SPECIFIC ACTION	• REQUIRES CORRECTIVE ACTION, BUT HAS NO IMPACT ON: - MOTOR PERFORMANCE - PROGRAM SCHEDULE • DOES NOT REDUCE USABILITY OF PART FOR ITS INTENDED FUNCTION • COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE IN COMBINATION WITH OTHER ANOMALY • SIGNIFICANT DEPARTURE FROM THE HISTORICAL DATA BASE	• COULD CAUSE FAILURE IN COMBINATION WITH OTHER ANOMALY • COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE • PROGRAM ACCEPTANCE OF CAUSE, CORRECTIVE ACTION, AND RISK ASSESSMENT REQUIRED BEFORE SUBSEQUENT STATIC TEST/FLIGHT	• VIOLATES CEI SPEC REQUIREMENTS • COULD CAUSE FAILURE AND POSSIBLE LOSS OF MISSION/LIFE • MANDATORY RESOLUTION BEFORE SUBSEQUENT STATIC TEST/FLIGHT

NOTE: THIS CRITERIA IS TO BE APPLIED TO THE SPECIFIC OBSERVED "POTENTIAL ANOMALY" AS IT RELATES TO THE OBSERVED ARTICLE AND AS IT RELATES TO SUBSEQUENT ARTICLES.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

DESCRIPTION: THE EA913 NA ADHESIVE USED TO BOND THE STS-27A COWL INSULATION TO THE COWL HOUSING EXTRUDED INTO THE RADIAL RTV BONDLINE (JOINT 2) BETWEEN THE COWL RING AND NOSE CAP, 360-DEG CIRCUMFERENTIALLY. THE EA913 NA THAT EXTRUDED INTO THE RADIAL BONDLINE WAS TYPICALLY SANDWICHED BETWEEN TWO LAYERS OF RTV. SOOT WAS OBSERVED BETWEEN THE ADHESIVE & RTV, AND TO THE HIGH PRESSURE SIDE OF THE PRIMARY O-RING INTERMITTENTLY AROUND THE CIRCUMFERENCE. DISTINCT BLOWPATHS WERE OBSERVED AT 4 LOCATIONS.

AT 296 DEG THE NOSE CAP AFT END GCP INSULATOR WAS HEAT EFFECTED (CHARRED 0.002 TO 0.005 IN. DEEP) IN LINE WITH A BLOWPATH. METAL COMPONENTS IN THE JOINT SHOWED NO SIGNS OF HEAT DAMAGE. THERE WAS NO BLOWBY, EROSION OR HEAT EFFECT TO THE PRIMARY O-RING.



NOSE INLET/BEARING/COWL JOINT 2

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

HISTORY:

THE MIXING OF EA913 ADHESIVE IN THE RTV COWL/NOSE CAP BONDLINE AND THE PRESENCE OF SOOT IN THE JOINT WERE DOCUMENTED ON ETM-1A, DM-8, DM-9, QM-6, QM-7 AND STS-26A & B. CHARRED INSULATORS AT BLOWPATH LOCATIONS HAVE BEEN OBSERVED IN THE RSRM DESIGN JOINT # 2 ON QM-6, AND STS-26A. THESE WERE ALL CLASSIFIED AS "MINOR ANOMALIES" IN THE PAST BASED ON THE JUSTIFICATION THAT THE ADHESIVE EXTRUDING INTO THE RTV BONDLINE REDUCED THE CAPABILITY OF THE RTV TO ACT AS A THERMAL BARRIER. WE RECOMMENDED CHANGING THE ASSEMBLY PROCESS TO ELIMINATE THE RTV/ADHESIVE MIXING (PV-1 & QM-8).

THERE HAS ALSO NEVER BEEN PRIMARY O-RING BLOWBY, EROSION OR HEAT EFFECT OR METAL COMPONENT HEAT DAMAGE OBSERVED IN JOINT #2.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

TEAM CLASSIFICATION: OBSERVATION

RELIABILITY RECOMMENDATION: NO SIGNIFICANT PROBLEM REPORT (SPR)

JUSTIFICATION: ALTHOUGH THERE IS NO ADHESION BETWEEN THE RTV AND ADHESIVE WHICH REDUCES THE CAPABILITY OF THE RTV TO ACT AS A THERMAL BARRIER, THERE HAS NEVER BEEN PRIMARY O-RING BLOWBY, EROSION OR HEAT EFFECT OBSERVED IN THE RSRM DESIGN JOINT #2. THERE HAS ALSO NEVER BEEN METAL COMPONENT HEAT DAMAGE OBSERVED IN THIS JOINT.

JOINT RTV PERFORMANCE ACCEPT/REJECT LIMITS (APPROVED BY MSFC) HAVE BEEN ADDED TO TWR-18680 VOL 5 AND TWR-17198 VOL 5, "KSC AND CLEARFIELD PEEL" DOCUMENTS. THE OBSERVED CONDITIONS DO NOT VIOLATE THESE LIMITS.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

RECOMMENDATION: CONTINUE EVALUATING NEW ASSEMBLY PROCESS CHANGE TESTED ON PV-1 AND QM-8 BY INCORPORATING ON TEM JOINT #2's. IF BACKFILL DEPTHS BECOME CONSISTENT, INCORPORATE NEW PROCESS CHANGE ON FLIGHT MOTORS.

REDUCE ALL OLD "MINOR ANOMALIES" ON THIS OBSERVATION TO "OBSERVATIONS" AND CLOSE OUT BASED ON THE JUSTIFICATION PRESENTED.

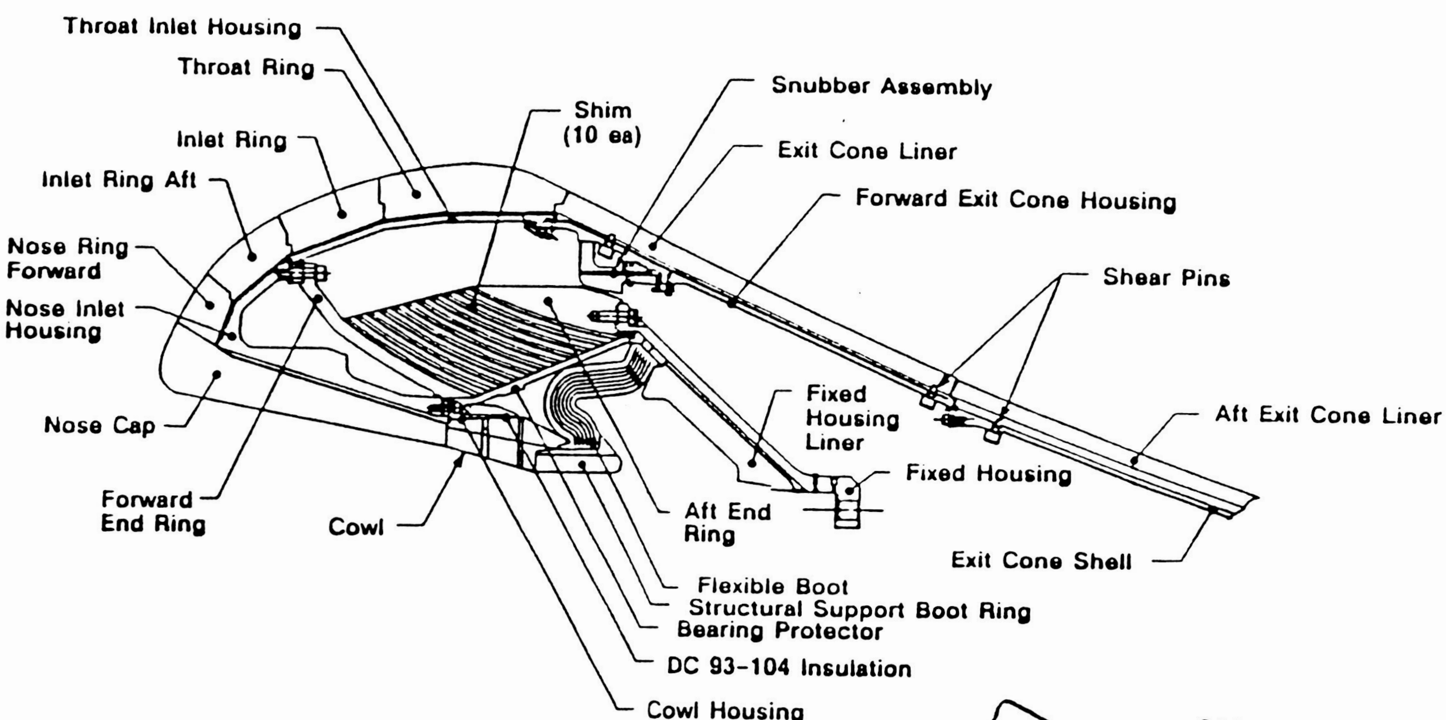
STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

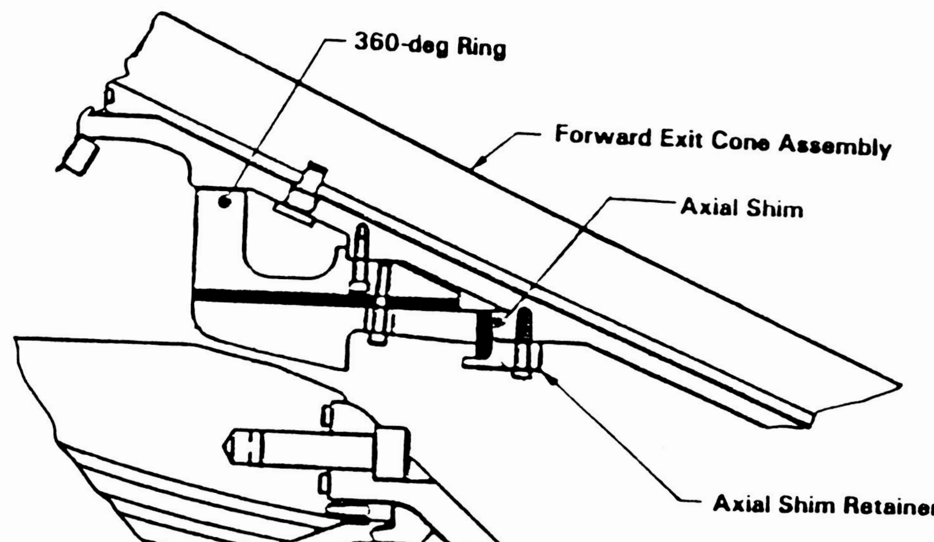
DESCRIPTION: THE STS-27B SNUBBER RETAINER BOLT HEADS WERE SHEARED OFF FROM 270 TO 340 DEG (13 BOLTS) DURING BEARING AFT END RING IMPACT OCCURRING AT SPLASHDOWN. THE BEARING AFT END RING SHOWED NO METAL DAMAGE, ONLY PAINT SCRATCHES. THE FORWARD EXIT CONE HOUSING SHOWED NO VISIBLE DAMAGE FOLLOWING THE REMOVAL OF THE SHEARED BOLTS AND SNUBBER RETAINERS.

HISTORY: FIRST TIME OBSERVED

TEAM CLASSIFICATION: AWAITING POSTFLIGHT BEARING ACCEPTANCE TESTING

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS





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STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

RELIABILITY RECOMMENDATION: AWAITING POSTFLIGHT BEARING ACCEPTANCE TESTING

RECOMMENDATION: COMPLETE STANDARD POSTFLIGHT BEARING ACCEPTANCE TESTING. IF PAD UNBOND AREA, AND TENSILE LEAK CHECKS ARE ACCEPTABLE, RECOMMEND CLASSIFYING THIS OBSERVATION AS A "MINOR ANOMALY" BASED ON THE JUSTIFICATION THAT THE SHEARED SNUBBER RETAINER BOLTS ARE A SIGNIFICANT DEPARTURE FROM OUR DATA BASE.

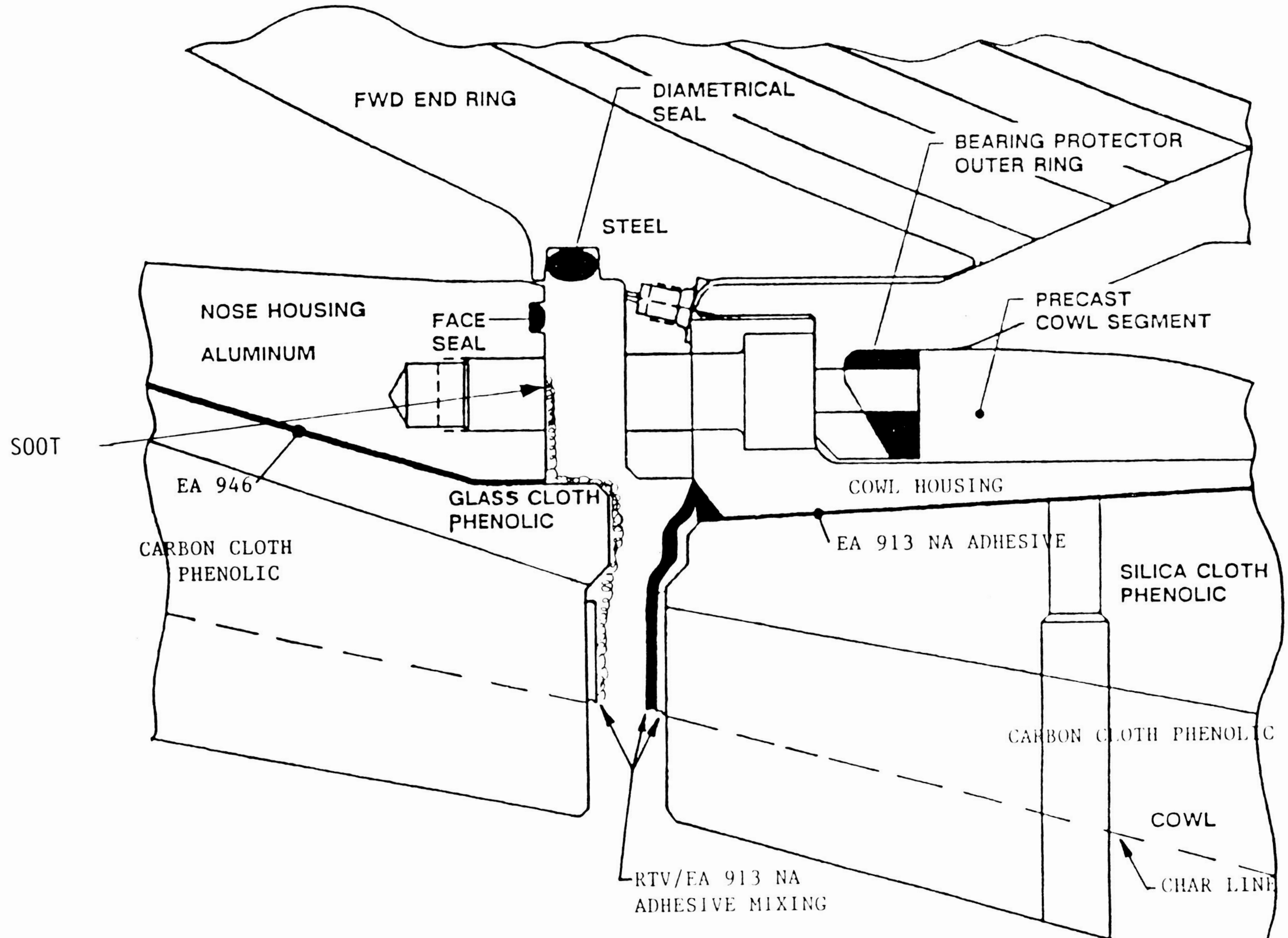
INSPECT FOR FUTURE OCCURRENCE. ADD ACCEPT/REJECT LIMITS TO KSC AND CLEARFIELD PEEL DOCUMENTS IF OBSERVED IN FUTURE.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

DESCRIPTION: THE EA913 NA ADHESIVE USED TO BOND THE STS-27B COWL INSULATION TO THE COWL HOUSING EXTRUDED INTO THE RADIAL RTV BONDLINE (JOINT 2) BETWEEN THE COWL RING AND NOSE CAP, 360-DEG CIRCUMFERENTIALLY. THE EA913 NA THAT EXTRUDED INTO THE RADIAL BONDLINE WAS TYPICALLY SANDWICHED BETWEEN TWO LAYERS OF RTV. SOOT WAS OBSERVED BETWEEN THE ADHESIVE & RTV, AND TO THE JOINT AXIAL BOLT HOLES INTERMITTENTLY AROUND THE CIRCUMFERENCE. THERE WERE NO DISTINCT BLOWPATHS OBSERVED IN THE JOINT.

METAL COMPONENTS IN THE JOINT SHOWED NO SIGNS OF HEAT DAMAGE. THERE WAS NO BLOWBY, EROSION OR HEAT EFFECT TO THE PRIMARY O-RING.

HISTORY: THE MIXING OF EA913 ADHESIVE IN THE RTV COWL/NOSE CAP BONDLINE AND THE PRESENCE OF SOOT IN THE JOINT WERE DOCUMENTED ON ETM-1A, DM-8, DM-9, QM-6, QM-7, STS-26A & B AND STS-27A. THESE WERE ALL CLASSIFIED AS "MINOR ANOMALIES" IN THE PAST BASED ON THE JUSTIFICATION THAT THE ADHESIVE EXTRUDING INTO THE RTV BONDLINE REDUCED THE CAPABILITY OF THE RTV TO ACT AS A THERMAL BARRIER. WE RECOMMENDED CHANGING THE ASSEMBLY PROCESS TO ELIMINATE THE RTV/ADHESIVE MIXING (PV-1 & QM-8).



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NOSE INLET/BEARING/COWL JOINT 2

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THERE HAS ALSO NEVER BEEN PRIMARY O-RING BLOWBY, EROSION OR HEAT EFFECT OR METAL COMPONENT HEAT DAMAGE OBSERVED IN JOINT #2.

TEAM CLASSIFICATION: OBSERVATION

RELIABILITY RECOMMENDATION: NO SIGNIFICANT PROBLEM REPORT

JUSTIFICATION: ALTHOUGH THERE IS NO ADHESION BETWEEN THE RTV AND ADHESIVE WHICH REDUCES THE CAPABILITY OF THE RTV TO ACT AS A THERMAL BARRIER, THERE HAS NEVER BEEN PRIMARY O-RING BLOWBY, EROSION OR HEAT EFFECT OBSERVED IN THE RSRM DESIGN JOINT #2. THERE HAS ALSO NEVER BEEN METAL COMPONENT HEAT DAMAGE OBSERVED IN THIS JOINT.

JOINT RTV PERFORMANCE ACCEPT/REJECT LIMITS (APPROVED BY MSFC) HAVE BEEN ADDED TO TWR-18680 VOL 5 AND TWR-17198 VOL 5, "KSC AND CLEARFIELD PEEL" DOCUMENTS. THE OBSERVED CONDITIONS DO NOT VIOLATE THESE LIMITS.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

RECOMMENDATION: CONTINUE EVALUATING NEW ASSEMBLY PROCESS CHANGE TESTED ON PV-1 AND QM-8 BY INCORPORATING ON TEM JOINT #2's. IF BACKFILL DEPTHS BECOME CONSISTENT, INCORPORATE NEW PROCESS CHANGE ON FLIGHT MOTORS.

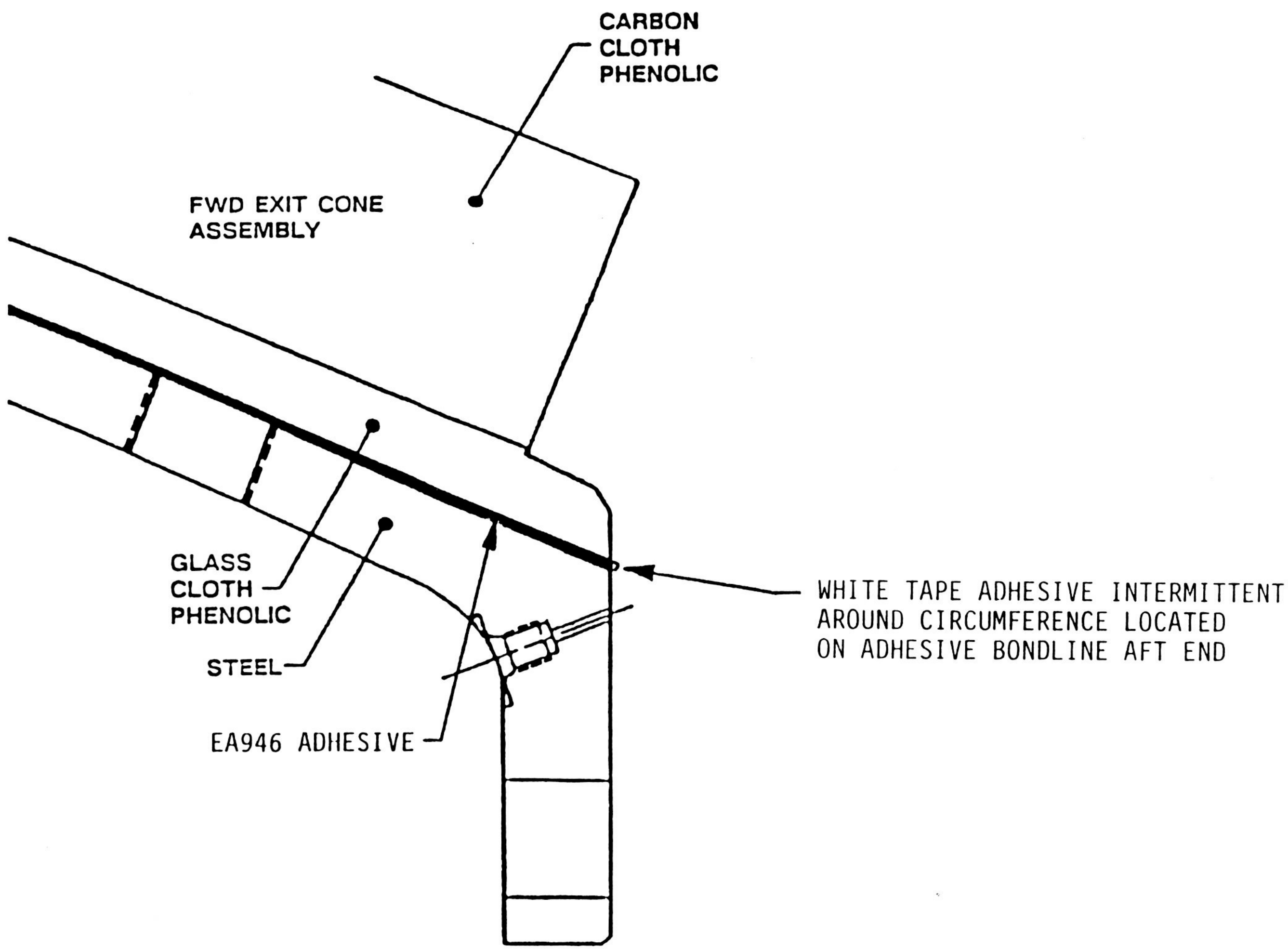
REDUCE ALL OLD "MINOR ANOMALIES" ON THIS OBSERVATION TO "OBSERVATIONS" AND CLOSE OUT BASED ON THE JUSTIFICATION PRESENTED.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

PR # PV6-116619

DESCRIPTION: FOLLOWING AFT EXIT CONE DEMATE, A WHITE RUBBERY SUBSTANCE WAS OBSERVED ON THE FWD. EXIT CONE EA946 ADHESIVE BONDLINE AFT END. THE WHITE SUBSTANCE WAS OBSERVED INTERMITTENTLY AROUND THE CIRCUMFERENCE ON BOTH THE (RH) AND (LH) NOZZLES. LAB ANALYSIS SHOWED THE SUBSTANCE TO BE TEFLON TAPE ADHESIVE.

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS



STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

HISTORY: FIRST TIME OBSERVED.

M-113 PLACES TAPE ON THE FORWARD EXIT CONE PHENOLICS AFT END TO PROTECT THE PHENOLICS FROM GREASE. KSC RECEIVES THE AFT SEGMENT/NOZZLE ASSEMBLY WITH THE TAPE ON THE FORWARD EXIT CONE PHENOLICS AFT END.

THE KSC OMI HAS AN INSPECTION STEP REQUIRING PERSONEL TO REMOVE THE TAPE, CLEAN AND INSPECT THE FORWARD EXIT CONE AFT PHENOLIC AND METAL SURFACES.

TEAM CLASSIFICATION: MINOR ANOMALY

RELIABILITY RECOMMENDATION: NO SIGNIFICANT PROBLEM REPORT

STS-27 NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

JUSTIFICATION: SIGNIFICANT DEPARTURE FROM DATA BASE

REQUIRES CORRECTIVE ACTION BUT HAS NO IMPACT ON MOTOR PERFORMANCE OR PROGRAM SCHEDULE. THE TAPE ADHESIVE DOES NOT INTERFERE WITH THE PRIMARY O-RING SEAL.

RECOMMENDATION: THIS PR HAS BEEN FORWARDED TO MTI-LSS OFFICE FOR DISPOSITION. RECOMMEND LSS OFFICE REVIEW ASSEMBLY INSPECTIONS AND PROCEDURES AND MAKE CHANGES TO PREVENT RECURRENCE

- STATUS: MTI ENGINEERNIG AND LSS ENGINEERING HAVE REVIEWED OPERATION INSTRUCTIONS FOR PROPER CLEANING AND INSPECTION STEPS. STEPS ARE SUFFICIENT TO NOT ALLOW CONTAMINATION. LSS ENGINEERING HAS DISCUSSED THIS PARTICULAR PR WITH OPERATIONS PERSONNEL AND STRESSED ATTENTION TO DETAILS IN REGARD TO CONTAMINATION

4-5-89

360L003 (STS-29) NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THE NOZZLE COMPONENT PROGRAM TEAM CONVENED 30 MARCH 1989. THE TEAM REVIEWED ALL OBSERVATIONS AND ALL PR'S THAT WERE GENERATED DURING DISASSEMBLY OF THE STS-29 NOZZLE HARDWARE AT KSC.

- 6 NOZZLE SQUAWKS WERE WRITTEN AT KSC
- 3 PR'S WERE GENERATED FROM THE SQUAWKS AT KSC
- THE NOZZLE COMPONENT PROGRAM TEAM CLASSIFIED 1 PR AS AN "OBSERVATION", 1 PR AS A "MINOR ANOMALY" AND ARE AWAITING REFURBISHMENT INFORMATION OF THE THIRD PR BEFORE CLASSIFYING.

360L003 (STS-29)
NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

THE NOZZLE COMPONENT PROGRAM TEAM CONSISTS OF THE FOLLOWING MEMBERS:

PROGRAM OFFICE	D. NISONGER
PROGRAM MANAGEMENT	E. DIEHL*
PROJECT ENGINEERING	D. WAGNER*
DESIGN ENGINEERING	
o NOZZLE DESIGN	S. MEYER,* R. GEORGE,* L. WILKES*
o NOZZLE STRUCTURES	D. BRIGHT
o SEALS	K. BAKER*
SYSTEMS ENGINEERING	
o P & AD	J. BAILEY*
RELIABILITY	J. RICHARDS,* G. CONOVER
QUALITY ASSURANCE	G. NIELSON*
MANUFACTURING ENGINEERING	J. LEIBOLD*

* STS-29 ATTENDEES

ANOMALY CLASSIFICATION CRITERIA:

REMAINS OBSERVATION	ANOMALY		
	MINOR	MAJOR	Critical
• REQUIRES NO SPECIFIC ACTION	• REQUIRES CORRECTIVE ACTION, BUT HAS NO IMPACT ON: – MOTOR PERFORMANCE – PROGRAM SCHEDULE • DOES NOT REDUCE USABILITY OF PART FOR ITS INTENDED FUNCTION • COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE IN COMBINATION WITH OTHER ANOMALY • SIGNIFICANT DEPARTURE FROM THE HISTORICAL DATA BASE	• COULD CAUSE FAILURE IN COMBINATION WITH OTHER ANOMALY • COULD CAUSE DAMAGE PREVENTING REUSE OF HARDWARE • PROGRAM ACCEPTANCE OF CAUSE, CORRECTIVE ACTION, AND RISK ASSESSMENT REQUIRED BEFORE SUBSEQUENT STATIC TEST/FLIGHT	• VIOLATES CEI SPEC REQUIREMENTS • COULD CAUSE FAILURE AND POSSIBLE LOSS OF MISSION/LIFE • MANDATORY RESOLUTION BEFORE SUBSEQUENT STATIC TEST/FLIGHT

NOTE: THIS CRITERIA IS TO BE APPLIED TO THE SPECIFIC OBSERVED "POTENTIAL ANOMALY" AS IT RELATES TO THE OBSERVED ARTICLE AND AS IT RELATES TO SUBSEQUENT ARTICLES.

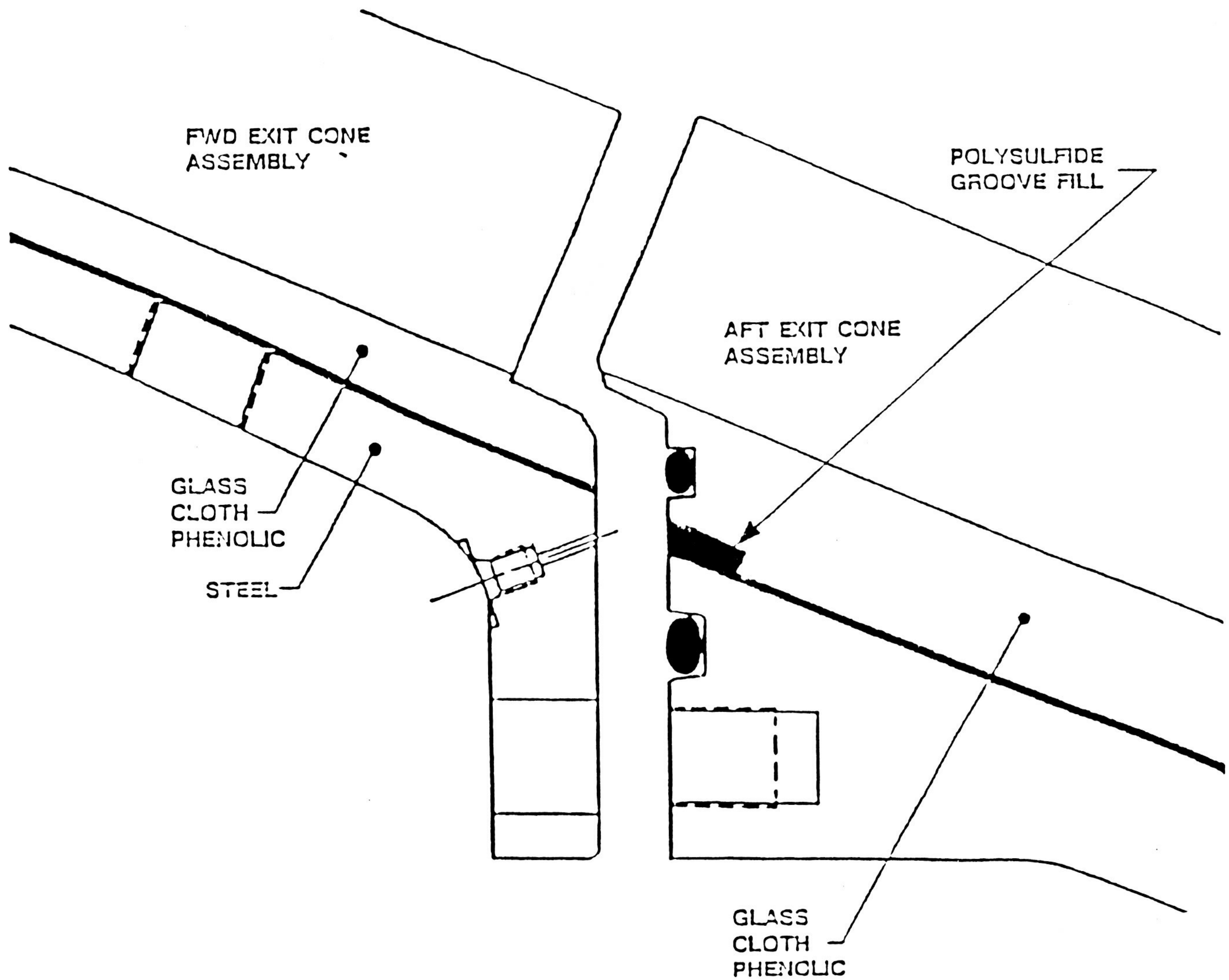
360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

PR 360L003A-04

DESCRIPTION: THE STS-29 (LH) AFT EXIT CONE FIELD JOINT SHOWED SPLASHDOWN DAMAGE FROM 56 TO 206 DEG.

- A SEPARATION (MAX WIDTH OF 0.25 IN) COULD BE SEEN BETWEEN THE AFT EXIT CONE (AEC) SHELL AND THE FORWARD EXIT CONE (FEC) HOUSING FROM 80 TO 180 DEG.
- THE PRIMARY O-RING WAS MISSING EXCEPT FOR A 3 IN. SECTION. THIS PIECE WAS CAUGHT IN A SEPARATION BETWEEN THE FEC AFT END GCP INSULATOR AND STEEL HOUSING.
- THE SECONDARY O-RING WAS SEVERED IN TWO PLACES WITH THE 71 TO 198 DEG ARC COMPLETELY MISSING.
- HELICOILS WERE PULLED FROM THE AEC THREADED HOLES FROM 71 TO 198 DEG. THE AEC ALUMINUM THREADS WERE STRIPPED IN THIS RANGE.
- THREE BOLTS WERE BROKEN AT 131, 135 AND 142 DEG. THE REMAINING SCREWS IN THE 56 TO 206 DEG RANGE SHOWED BENDING, FLATTENED THREADS AND DINGS.

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS



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360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

DESCRIPTION (CONT.):

- THE BOLTS AND HELICOILS FROM 210 TO 360 TO 52 DEG SHOWED NO DAMAGE.

HISTORY: THE STS-27B (RH) AEC FIELD JOINT SHOWED BENT BOLTS IN THE 0 TO 90 DEG QUADRANT. THIS WAS RECOMMENDED TO BE CLASSIFIED AS A "MINOR ANOMALY" TO THE RPRB BASED ON THE JUSTIFICATION THAT IT WAS A SIGNIFICANT DEPARTURE FROM OUR DATA BASE, AND THAT STRUCTURES CONCLUDED THE BOLTS WERE BENT AT SPLASHDOWN (MEMO L223:FY89:639). THE RPRB GAVE THE ACTIONS TO WAIT AND SEE IF CLEARFIELD REFURBISHMENT FOUND ANY DAMAGE TO THE AEC OR FEC, AND TO ANALYZE THE BENT BOLTS BEFORE CLASSIFYING. THE STS-27B AEC HELICOILS AND THREADED HOLES, AND THE FEC AFT FLANGE THROUGH HOLES SHOWED NO DAMAGE. LAB TESTS SHOWED HARDNESS AND TENSILE PROPERTIES OF THE BENT BOLTS WERE ACCEPTABLE. VENDOR CERTIFICATIONS WERE ALSO REVIEWED AND FOUND TO BE ACCEPTABLE PER MTI BOLT SPEC STW3-1553. BENT BOLTS HAVE BEEN ADDED TO THE NOZZLE PEEL DOCUMENT (TWR-18680 VOL 5) AS A "REPORTABLE" CONDITION.

RELIABILITY RECOMMENDATION: AWAITING STS-29 REFURBISHMENT INFORMATION

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

TEAM CLASSIFICATION: AWAITING STS-29 REFURBISHMENT INFORMATION

RECOMMENDATIONS/CORRECTIVE ACTIONS:

- RUN HARDNESS AND TENSILE TESTS ON STS-29A AEC FIELD JOINT BOLTS. ALSO REVIEW VENDOR CERTIFICATIONS ON BOLTS.
  STATUS: IN WORK

- HAVE STRUCTURES REVIEW STS-29A INSTRUMENTATION DATA TO VERIFY THE HARDWARE DAMAGE OCCURRED AT SPLASHDOWN.

  STATUS: STRUCTURES COMPLETED THE FEC AND AEC STRAIN GAGE DATA REVIEW THROUGH 500 SEC AND CONCLUDED THAT THE STS-29A AEC FIELD JOINT DAMAGE OCCURRED AT SPLASHDOWN.

- IF THE 360L003A (STS-29A) AFT EXIT CONE IS NOT REUSABLE CLASSIFY THIS AS A "CRITICAL ANOMALY". THIS IS A VIOLATION OF THE CEI SPECIFICATION (PARAGRAPH 3.2.1.9) WHICH REQUIRES 19 RE-USES OF NOZZLE METAL HARDWARE. IF THE AEC SHELL IS REUSABLE, CLASSIFY THIS AS A "MAJOR ANOMALY" BASED ON THE POSSIBILITY OF DAMAGE PREVENTING REUSE OF HARDWARE.

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360L003 (STS-29) NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

RECOMMENDATINS/CORRECTIVE ACTIONS (CONT.):

RECOMMEND CLOSING OUT THIS ANOMALY IF THE STS-29A BOLT PROPERTIES AND VENDOR CERTIFICATIONS ARE ACCEPTABLE.

- CLASSIFY THE STS-27B BENT BOLTS OBSERVATION AS A "MINOR ANOMALY" BASED ON THE FACT THAT THE BENT BOLTS WERE A SIGNIFICANT DEPARTURE FROM OUR DATA BASE AT THE TIME, AND THEY COULD CAUSE DAMAGE PREVENTING RE-USE OF THE FEC AND AEC IF HIGHER SPLASHDOWN LOADS ARE ENCOUNTERED. ALSO CLOSE OUT THE STS-27B ANOMALY BECAUSE RPRB RECOMMENDED ACTIONS WERE COMPLETED AND IT WAS CONCLUDED THAT THE BENT BOLTS RESULTED FROM SPLASHDOWN LOADS.

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

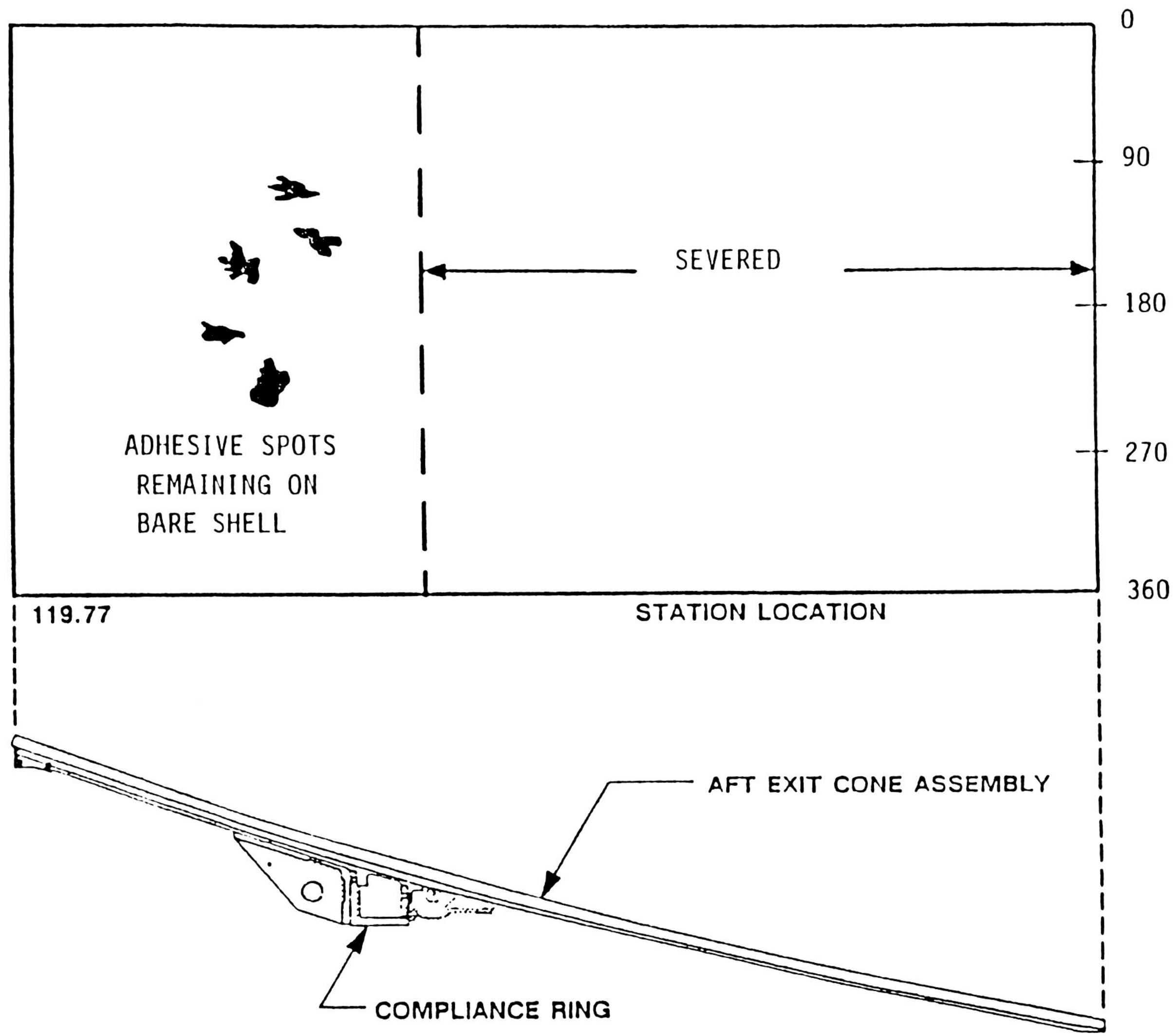
PR 360LOO3A-06

DESCRIPTION: THE STS-29A (LH) AFT EXIT CONE SHOWED MISSING CCP LINER AND GCP INSULATOR OVER APPROXIMATELY 95% OF THE SHELL. THE EXPOSED ALUMINUM SHELL SHOWED NO SIGNS OF HEAT EFFECT INDICATING THE PHENOLICS WERE TORN OFF AT SPLASHDOWN. FIVE (5) SPOTS OF ADHESIVE REMAINED BONDED TO THE AEC SHELL AT 98, 153, 168, 205 AND 235 DEG (TOTAL OF LESS THAN 5% OF AEC SHELL SURFACE AREA). THE REST OF THE ADHESIVE WAS PULLED OFF THE CONE WITH THE PHENOLICS AT SPLASHDOWN.

THE 5 REMAINING SPOTS OF ADHESIVE SHOWED GLOSSY FINISHES AT THE GCP INTERFACE INDICATING BONDLINE VOIDS WERE PRESENT. THE PR IS CONCERNED WITH THE ACCEPTABILITY OF THE VOIDS AND THAT THEY MAY HAVE CONTRIBUTED TO THE LOSS OF THE AEC PHENOLICS.

HISTORY: VOIDS WERE OBSERVED ON THE STS-27B (RH) AEC SHELL BONDLINE WHERE THE LINER AND INSULATOR WERE MISSING FROM SPLASHDOWN. THESE WERE DOCUMENTED AND CLASSIFIED AS "OBSERVATIONS".

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS



360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

RELIABILITY RECOMMENDATION: SPR DR4-5/142, THIS WAS WRITTEN UP AS AN IN FLIGHT ANOMALY (IFA).

TEAM CLASSIFICATION: ~~OBSERVATION~~

SIGNIF. DEPARTURE F

JUSTIFICATION: AIR ENTRAPMENT VOIDS OBSERVED IN AEC SHELL BONDLINES ARE EXPECTED AND DO NOT AFFECT PERFORMANCE.

RESULTS OF STRUCTURAL ANALYSES (TWR-16975) SHOW THAT THE AEC PHENOLICS WILL REMAIN IN THE SHELL DURING MOTOR BURN WITH CONSERVATIVE ASSUMPTIONS, INCLUDING NO ADHESIVE STRENGTH.

IN ADDITION, AEC SEVERANCE AT APOGEE MAY HAVE CONTRIBUTED TO THE LOSS OF THE PHENOLICS AT SPLASHDOWN. ADDITIONAL HEATING OF THE SHELL EXTERIOR FOLLOWING SEVERANCE INCREASED THE EA946 BONDLINE TEMPERATURE BY SPLASHDOWN:

STS-29	295	F	MAX (SEVERED AT APOGEE)
STS-27	150	F	MAX
STS-26	195	F	MAX

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

PR 360L003A-10

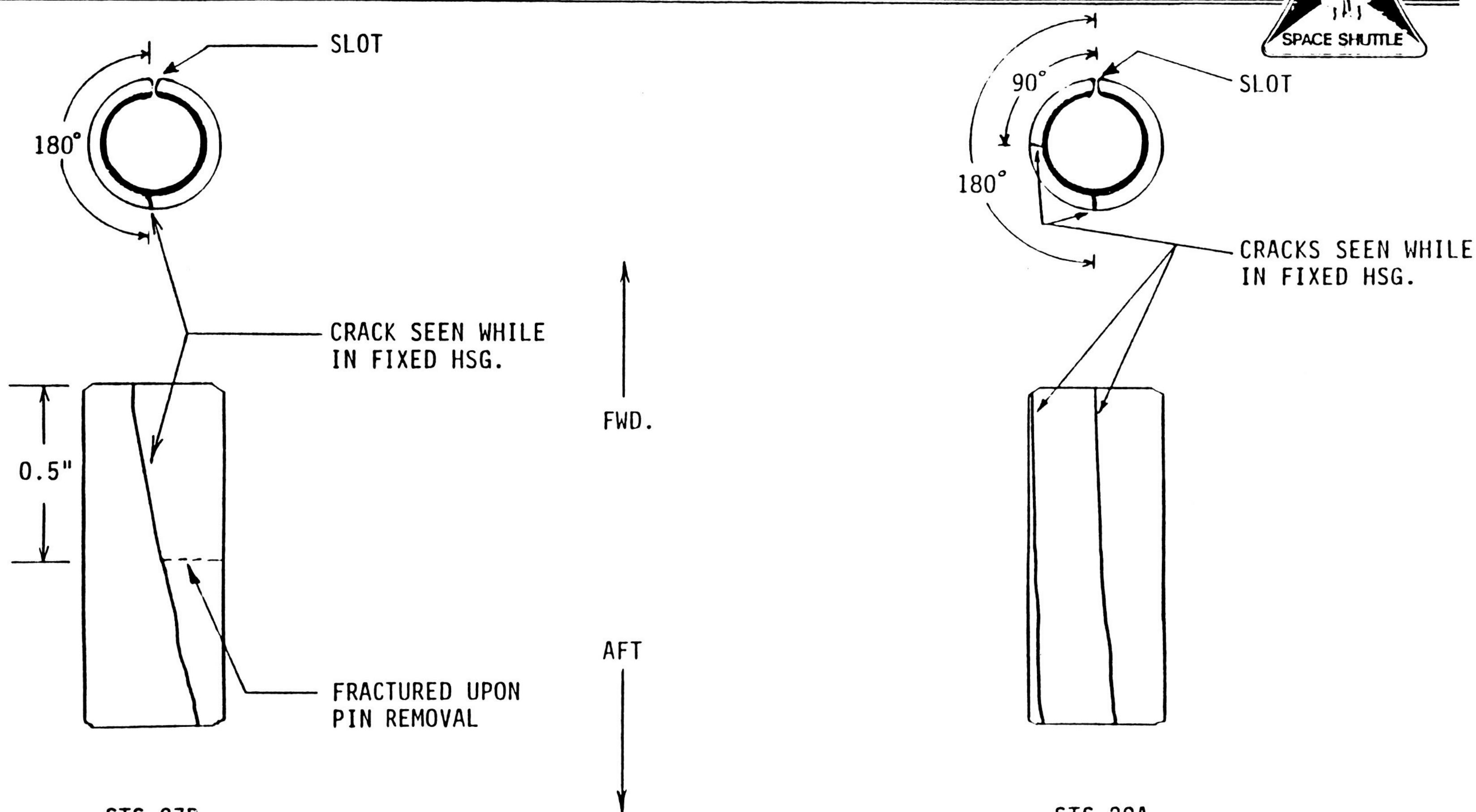
DESCRIPTION: THE ALIGNMENT PIN ON THE STS-29A (LH) FIXED HOUSING AFT END (NOZZLE /CASE JOINT) SHOWED TWO AXIAL CRACKS EXTENDING THE LENGTH OF THE PIN.

THE PR BOARD THAT ELEVATED THIS SQUAWK TO A PR WAS CONCERNED WITH THE POSSIBILITY OF FRACTURING A PIECE OF THE PIN OFF AT ASSEMBLY, AND HAVING THE CHIP INTERFERE WITH A SEAL.

THE FIXED HOUSING AFT END ALIGNMENT PIN IS A MS16562, 410 OR 420 CRES PIN MODIFIED TO A 0.97-1.03 IN. LENGTH.

HISTORY: THE STS-27B (RH) FIXED HOUSING AFT END ALIGNMENT PIN SHOWED ONE CRACK EXTENDING THE AXIAL LENGTH OF THE PIN. THE RPRB GAVE THE ACTION TO HAVE METALLURGY EXAMINE THE PIN AND CRACK AND REPORT BACK WITH THEIR FINDINGS, BEFORE CLASSIFYING.

METALLURGY EXAMINED THE CRACK SURFACES AND CONCLUDED THAT THE STS-27B ALIGNMENT PIN CRACK WAS PRESENT PRIOR TO DISASSEMBLY (MEMO 2421-FY89-97).



STS-27B
FIXED HOUSING
ALIGNMENT PIN

STS-29A
FIXED HOUSING
ALIGNMENT PIN

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

RELIABILITY RECOMMENDATION: NO SPR

TEAM CLASSIFICATION: MINOR ANOMALY

JUSTIFICATION: THIS IS NOT A HARDWARE REUSE ISSUE. THE CRACK DOES NOT REDUCE THE USABILITY OF THE ALIGNMENT PIN FOR ITS INTENDED FUNCTION. THE PINS ARE USED ONLY ONCE.

FRACTURED ALIGNMENT PINS HAVE NEVER BEEN OBSERVED, ONLY CRACKED PINS. CONTACT OF THE ALIGNMENT PIN WITH THE AFT DOME HAS NOT BEEN OBSERVED DURING NOZZLE/CASE JOINT ASSEMBLY.

RECOMMENDATIONS/CORRECTIVE ACTIONS:

AN INSPECTION POINT WAS ADDED TO PLANNING TO INSPECT THE ALIGNMENT PIN AFTER BEING INSTALLED IN THE FIXED HOUSING.

- o EFFECTIVE: RSRM FLIGHT 6

360L003 (STS-29) NOZZLE COMPONENT PROGRAM TEAM RECOMMENDATIONS

RECOMMENDATINS/CORRECTIVE ACTIONS (CONT.):

HAVE MANUFACTURING REVIEW AND MAKE CHANGES TO THE NOZZLE/CASE JOINT ASSEMBLY PLANNING, IF NECESSARY, TO AVOID ALIGNMENT PIN CONTACT AND OBSERVE THE PIN DURING ASSEMBLY.

- STATUS: IN WORK

ADD CRACKED ALIGNMENT PINS AS A "REPORTABLE" CONDITION TO THE NOZZLE PEEL DOCUMENT. INSPECT FUTURE ALIGNMENT PINS FOR CRACKS AND CLOSE OUT THIS ANOMALY IF CRACKS ARE NO LONGER OBSERVED FROM RSRM FLIGHTS 6 TO 9.

CLASSIFY THE STS-27B (RH) ALIGNMENT PIN CRACK AS A "MINOR ANOMALY" BASED ON THE FACT THAT IT WAS A DEPARTURE FROM OUR DATA BASE, AND THAT IT IS NOT A HARDWARE REUSE ISSUE. CLOSE OUT THIS ANOMALY IF CRACKS ARE NO LONGER OBSERVED FROM RSRM FLIGHTS 6 TO 9.

360L003 (STS-29) NOZZLE COMPONENT PROGRAM
TEAM RECOMMENDATIONS

RECOMMENDATIONS/CORRECTIVE ACTIONS:

REVIEW THE STS-29A (LH) AEC BONDING LOG FOR DEPARTURES.

- STATUS: REVIEW OF THE BONDING LOG SHOWED THAT NO DR'S OR PD'S WERE INITIATED. STANDARD BONDLINE REPAIRS WERE CONDUCTED ON THE FORWARD END OF THE AEC ASSEMBLY. ONE EDGE VOID (2.4 IN. AXIAL, 0.64 IN. CIRC., 0.040 IN. RAD) EXCEEDED THE ALLOWABLE REPAIR CRITERIA THAT EXISTS IN THE PLANNING. DL #95250 WAS INITIATED TO DOCUMENT THIS VOID. THE DISPOSITION WAS COORDINATED WITH NOZZLE DESIGN ENGINEERING, AND THE VOID WAS FILLED PER STANDARD SHOP PLANNING.

REVISE THE KSC NOZZLE PEEL DOCUMENT (TWR-18860 VOL 5) TO SHOW THAT AEC SHELL BONDLINE VOIDS ARE "ACCEPTABLE". CLASSIFY ALL FUTURE OCCURRENCES AS OBSERVATIONS.

RECOMMEND CLOSING OUT THIS PR WHEN THE NOZZLE PEEL DOCUMENT IS REVISED.